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TELEPHONE ENGINEER

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Editorial Mention

Ownership of Utilities

People who regard the big utility concerns of the country as "close corporations," are usually laboring under delusions. The railroads, telephone, electric light and power concerns, street railways, and big corporate industries, are usually built from the wealth of all classes of people. For the United States is made up of a people who are investors. Mr. H. B. Thayer, president of the American Telephone & Telegraph Co., in a recent statement tells who owns the great concern of which he is the executive head. It appears that there are 135,000 owners of stock of that company, and about as many more owners of its bonds. There are 46,126 employes who have purchased stock.

In Illinois there are 275,000 men and women who own securities in the different utilities of the state.

Perhaps the war issues of liberty bonds served as an eye-opener to many people, who learned from their experiences that there are a great many securities on the market that furnish safe and profitable investment for their idle funds, and a good place for them to keep their "nest eggs."

Telephone Privacy

Many telephone subscribers express their resentment at the invasion of telephone rights by business and charity solicitors. They have been pestered especially by stock and automobile salesmen, but all kinds of commercial and philanthropic enterprise, good or bad, contribute to disturb their peace. They want to know whether there is any protection for a harassed housewife, or for a tired business man after office hours, against this particular form of annoyance.

It is a question of growing interest, the ethics of which are still to be determined. The evil is worst in big cities, but is also forcing attention in small ones. It is akin to the front-door evil that every housekeeper in any but the most thinly settled community soon comes to dread—the continual ringing of the doorbell by agents or hucksters or salesmen of some kind or other. The worst thing about the telephone is that many people who would not venture to intrude personally in a stranger's home seem to have no scruples about a telephonic intrusion, and call up at almost any hour without any consideration.

Is a home telephone really public property for anyone to use who can command the other end of the wire? Or is it a genuinely private institution, sacred to the use of friends and of such business as really concerns the owner? It is hard to know where to draw the business line, but some kind of line will have to be drawn if present tendencies continue.

Novel Use of Telephone

War is a stimulus to science, and this is reflected very strikingly in matters pertaining to the relief of the wounded. The search for and extraction of fragments of shells is no simple matter, although surgical endeavor has been facilitated by the perfection of the X-rays. But these are insufficient. A bullet may be located speedily, but the difficulty is to ascertain its precise position by the probe and lancet. As a result of study and investigation a simple and effective method of discovery has been perfected, which may be described as telephoning for bullets. Ordinary telephonic receivers are clamped over the surgeon's head, one wire being led to a carbon plate and the second wound round the knife, probe, needles, forceps or whatever instruments is used. With this implement the search is made, and directly it comes into contact with, say, a bullet, a distinct click is heard on the telephone. If the instrument is rubbed across the surface of the buried object a rattle is observed, and by following this clew it is possible to withdraw the bullet or fragment of metal. The idea is by no means new, inasmuch as it was employed for the first time during the Boer war; but the present campaign has served to bring it to a high state of perfection.

Long Distance to Cuba

Direct telephone communication between the United States and Cuba is to be provided by the Cuban-American Telephone & Telegraph Co., a permit for the landing of three telephone cables from Havana at Key West, Fla., has been granted the company by the state department at Washington. Laying of the cables is expected to be completed by spring, representatives of the company state. They will be approximately 100 miles in length or longer than any submarine telephone cables yet laid.

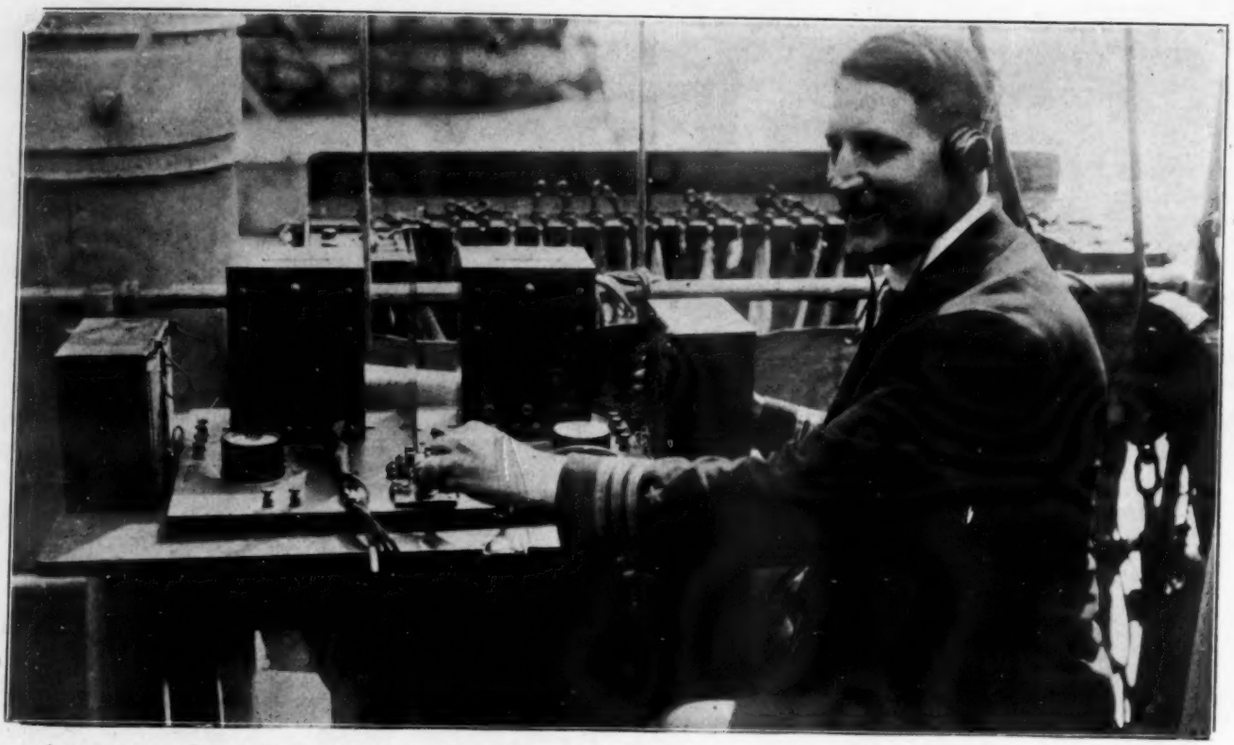
Of the three talking circuits to be provided, one will be connected directly with New York, it was said, so that the ring of the long distance operator in Havana will sound in the New York central office. A second circuit will pass through the Jacksonville, Fla, central office, for service to western states, and the third, will connect with the Key West exchange for calls to and from points in the south.

Construction of the cables, already completed, was said to have presented entirely new engineering problems, due to the depth of the waters to be traversed.

Telephone Growth

The growth of the telephone since its invention only 44 years ago has been amazing. Today there are approximately 12,500,000 telephones in use in the United States and the messages carried total over twenty-two billions per year or approximately 211 for each man, woman and child in the nation. There are nearly 30,000,000 miles of wire and this equipment cost the staggering total of two billions of dollars, about 700,000 individuals being owners of the securities.

New Method of Guiding Steamers Through Channels at Night



Apparatus on Board Steamer to Direct Its Movements to Dock by Detecting proximity to Parallel Cables.

Steamer Coming Into Dock Through Channel Picking Its Way by Running Between Two Cables.

Wireless Telegraphy and Telephony

Abstract of an Address before the Royal Society of Arts, London, England, November 17, 1920

By ALLAN A. CAMPBELL SWINTON, F.R.S.

AS is now well known, the transmission of wireless signals is effected by means of electro-magnetic waves. Until recently, these waves were supposed to consist of periodic motions of an all-pervading hypothetical medium extending throughout the universe, known as the ether of space. Professor Einstein's recent theory of the Principle of Relativity, and the results of certain astronomical experiments made to test this theory, have thrown some doubt on the necessity for, or the existence of, the ether; but though the exact nature of these electro-magnetic waves may be questioned, there is no doubt about their existence and their effects. They travel with the velocity of light, namely, at the rate of 186,000 miles per second, and appear, indeed, to be exactly similar to what we call light, except as regards their waves length and as regards the frequency of their vibration. Whereas the waves of visible light have a length to be measured in millionths of a millimeter and a frequency of billions per second, the waves used in wireless are seldom less than 100 m. in length, and may be as long as 20,000 m. or more. At the same time, their frequency is to be reckoned in millions down to thousands per second. These waves pass through brick walls, and through wood, glass, slate and plaster roofs and ceilings, practically without loss.

So far as is known, these waves, even the strongest of them, have no direct effect on any of the five senses which are the sole avenues whereby we appreciate anything that is external to ourselves. Directly, we can neither feel, hear, smell, taste or see them. Other methods have therefore to be adopted, and those hitherto used all consist of means whereby the received electro-magnetic waves are employed to generate electric currents or to cause variations in otherwise constant electric currents to an extent that, with the delicate instruments employed, is capable of observation. All the older stations comprised a wire aerial raised on masts, high above the earth, this aerial being connected to the earth through coils and condensers whose inductance and capacities tuned the whole apparatus so as to make it resonate to the incoming waves. As detectors, Lodge, Marconi and the early experimenters, used coherers, until these were superseded by the more sensitive crystal detectors. Now today, both for detecting the waves and for amplifying the currents, that wonderful piece of apparatus, the thermionic tube, has practically superseded everything else, and had rendered high aerials no longer necessary for receiving, though they are still used in many cases and are still necessary for transmitting over any considerable distance.

We have a small aerial of about 100 feet in length reaching from this lecture table to above the roof of the building, and I can connect this with the receiving apparatus on the table, which consists of an adjustable tuning con-

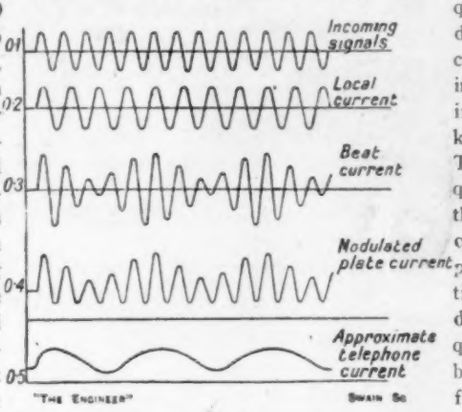


Fig. 1
Curves Illustrating Heterodyne Reception.

denser and a number of thermionic valve tubes arranged in cascade.

On some wave length or other—and I can vary the adjustments to receive different lengths—we are pretty certain at all hours of the day and night to receive signals. Indeed, when we adjust the apparatus to suit 600-meter messages at once, which may not be easy to disentangle from one another. This is for the reason that 600 m. is the wave length employed in the mercantile marine, and we thus get all the ships in the Thames, in the channel, or round the neighboring coasts, which may happen to be sending, as well as the coast stations at the North Foreland, Dover, Harwich, Havre, Dunkirk, Scheveningen, etc. All these are what is known as spark stations, in which the waves are generated by electric oscillations caused by sparks, and where the note heard in the receiving telephone is dependent upon the number of sparks per second in the transmitter.

Another system, and one that is coming more and more into use, is that which employs what are known as continuous waves, that is to say, waves that maintain a constant amplitude throughout the sending of a signal, such as a dot or a dash of the Morse alphabet, and do not vary in amplitude several times from maximum to zero during even a single dot as is the case in spark transmission. Such continuous waves are of course mostly of far too high a frequency to give a direct audible effect, even if the telephones could respond to such rapidly varying currents, which they cannot. The frequency of any but the very longest of these waves runs into figures of 50,000, to say, 500,000 per second, while the highest note audible to the average human ear has a frequency below 40,000. In order to render audible the signals sent by these continuous waves, a very beautiful and ingenious method called "heterodyning" is used. This is based on the well known acoustical phenomenon of beats. Two different notes having different frequencies, produce a third note due to the difference between the frequencies of the first two notes. In this way, by producing locally at the receiving station, an electrical oscillation only slightly differing in frequency from the frequency of the incoming signal, an audible note is obtained, and by varying the frequency of the local oscillation the audible note can be made of any convenient pitch, though alone either of the primary oscillations are of much too high a frequency to give any audible effect whatever. This method gives great selectivity, and enables several simultaneous incoming signals of only slightly different wave length to be distinguished from one another with marvelous nicety.

Fig. 1 shows diagrammatically the different stages of heterodyne reception. The top curve represents the incoming signals of too high a frequency to be audible. The second curve shows the local current also of too great frequency to be heard, but of a slightly different frequency from that of the signals. The third curve shows the resultant beat current, while the fourth is this beat current after it has been rectified. Finally, the bottom curve shows the variations in the current caused to pass through the telephones, these variations being of a frequency much lower than that of the incoming signals, and one that can readily be heard.

I will now describe some of the apparatus that we are going to use. Fig.

2 represents diagrammatically an amplifier containing seven thermionic tubes arranged in cascade, so as to magnify the received signals many thousands of times. Each thermionic tube or valve, as it is called, consists of a glass bulb exhausted to a very high degree of vacuum. Inside each bulb there are three electrodes, insulated from one another, but with terminals connected to them sealed through the glass walls of the bulb. The first of these electrodes is a filament of tungsten, just like the filament of an incandescent electric lamp, and, as will be observed, the filaments of all the seven valves are connected through a regulating rheostat to a 4-volt battery by which the filaments can be caused to become incandescent. Then, above, the filament in each bulb there is shown, by the dotted line, another electrode which is called the grid. In some forms of valves it is actually a grid made of fine wire netting, and hence its name; but in the actual valves I am using, it, in fact, consists of a small spiral of wire surrounding but not touching the filament, which is straight. Then there is a third electrode, shown by the thick black line at the top of each bulb, called the plate, which, in the type of valve we are using tonight, takes the shape of a metal cylinder fixed outside of the spiral that forms the grid, without touching either the grid or the filament. Further, connected between the filament and the plate of each valve there is connected, as you will observe, a battery giving about 80 volts, the negative pole of which is coupled to the filament. Now, under these conditions, when we cause the filaments to glow, there is an emission of negative ions across the vacuous space between each filament and each plate, which emission is equivalent to an electric current. But, for the negative ions to get from the filament to the plate, they have to pass through the interstices of the grid, and it is found that the electrical condition of the grid has an enormous influence on the amount of electricity that passes. If the grid is made positive it attracts the ions and assists the passage of the electric current; if it is made negative it repels the ions back on to the filament, and the strength of the electric current is reduced. The whole of modern wireless telegraphy is dependent upon this effect, which consists in the fact that very small electric charges applied to the grid enormously vary the negative current that flows from the filament to the plate

Then, as you will notice, the plate of one valve is connected through a small condenser to the grid of the next, and so on throughout the whole series. This is called connecting in cascade, and has the effect of causing each succeeding valve to multiply the variation in the current passing through the one behind it. The result is that the amount of magnification increases very rapidly with the number of valves you employ.

As will be observed, on the extreme left of Fig. 2 is shown a coil or loop of wire, the one end of which is connected to the grid of the first valve, and the other to all the filaments, as also to the "out" terminal of the instrument. Across the two ends of the loop there is also connected a variable condenser. This loop, or frame aerial, as it is also called, merely consists of a coil of copper wire of some 30 to 100 turns, and about a yard in diameter, placed with its plane vertical to the

We will now pass on to Fig. 3, which shows a further amplifier, or note magnifier, as it is sometimes called, which is connected to the "out" terminals of the seven-valve amplifier. This note magnifier serves still further to magnify the signals. It has three valves, but, as will be observed, the connection between the valves is not through condensers as in the seven-valve amplifier, but through small transformers with iron cores.

On the extreme right of this note magnifier is shown the receiving telephone T, as also two terminals, to which the recording and printing apparatus—to which I am coming shortly—can be connected.

In an address that I gave to the Wireless Society of London before the war,

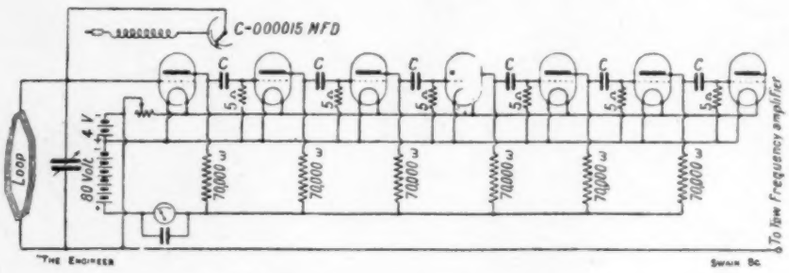


FIG. 2—SEVEN-VALVE RESISTANCE AMPLIFIER

ground. With such a loop when suitably tuned by means of the variable condenser, the waves from all the larger European wireless stations can be picked up inside a room like this with sufficient efficiency to operate an amplifier such as the one before you. Moreover, such a loop is directional, as, in order to get the strongest effect with it, it must be placed so that its plane passes through the sending station. Indeed, if turned at right angles to this position, the effect on the two sides of the loop is equal and opposite, and the signals die away altogether. In this way, with such a loop, the direction of the sending station can be located within a few degrees.

I have still to explain the purpose of the small adjustable condenser shown on the left-hand side at the top of Fig. 2. As will be observed, one plate of this condenser is connected to the grid of the first valve, while the other plate is connected to a loose plug at the end of a flexible wire. Now, this plug can be inserted in any one of six sockets connected with the plates of the six last valves, and the whole arrangement is for the purpose of causing the valves to set themselves into a state of oscillation in order to receive from a continuous-wave station by the system of heterodyning that I have already explained to you.

as long ago as January, 1914, I suggested that before long we might have a "wireless operated column printing telegraph machine in every house, telling the latest news to all the nation, as also to the newspapers, should any of these continue to survive the competition of this much more rapid method of disseminating intelligence," and in the address I gave to this Society—the Royal Society of Arts—in November, 1918, I enlarged upon the idea, pointing

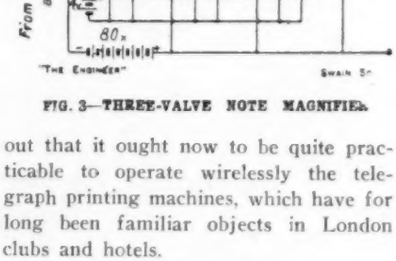


FIG. 3—THREE-VALVE NOTE MAGNIFIER

out that it ought now to be quite practicable to operate wirelessly the telegraph printing machines, which have for long been familiar objects in London clubs and hotels.

Tonight, I want to bring to your notice a further stage in the development of this idea, and to demonstrate to you by actual experiment how a telegraph instrument printing the messages it receives on paper in ordinary Roman type can be operated by wireless means

from places as distant as Paris and Portsmouth. The wonderful instrument with which I hope to show you this can be done was invented some years ago by F. G. Creed of Croydon, and is in regular use on wires between London and Glasgow, London and Edinburgh, London and Manchester ,and elsewhere, for newspaper use. It has been in use on wires for some considerable time, but it is only recently that it has been adapted to wireless transmission, and tonight is, I believe, the first occasion on which the printing in Roman type of wireless messages has been demonstrated in public. Mr. Creed's apparatus consists of two machines, the receiver and the printer. The first of these takes the Morse signals from a telegraph line—or, in our case tonight, from our wireless amplifiers—and records them by punching small holes in a moving strip of paper tape. This tape is then passed through the printer, which automatically converts the Morse signals into the appropriate Roman characters and prints them on a second paper tape.

Fig. 4 shows in diagrammatic form the construction of the receiver. It represents a special relay invented by Mr. Rupert Carpenter of the Creed Company. This relay has no electrical contacts, but its armature *b* is provided with a light tongue 1, to the free end of which is attached an exceedingly light balanced slide valve 2. This is adapted to control the supply of air to the small relay engine 3, the piston Aa of which is thus moved from side to side, in accordance with the Morse signals which actuate the relay tongue and are received through a second relay, from the wireless amplifiers. The movements of the piston 3a are transmitted by means of the rocking levers 4 to the piston valve 5 of the main engine, thus controlling the double-acting piston 6. From each side of this piston a rod projects through the cylinder cover and thrusts in either direction the adjacent arms of the three-armed bell-crank levers 7 and 8. Upon the arms 10 and 11 are hard steel strikers 12 and 13, the free ends of which are bifurcated for the purpose of thrusting against the adjacent heads of the rods 14 and punches 15. These rods and punches are mounted and guided in a separate block, with the die plates and the feed wheel spindle. The correcting rods 14 have flattened points 16, terminating in a V-shape — shown separately — and when thrust forward are adapted to enter the slots in the correcting wheels 17. Retracting springs are provided, as shown, to restore the rods and punches to their normal position against stops. The paper strip 18, which is previously centerholed is led up between the die plates, past the punches, and engages with the feed wheel 19, mounted upon the spindle 20, to which the correcting wheels 17 are also fixed. When the points 16 of any connecting-rod 14 are thrust by the striker between the teeth of the wheel 17, the rod adjusts and holds the latter, as well as the feed wheel 19, and the tape, in such a position that the corresponding punch 15 will perforate the paper exactly opposite the feed holes. Mounted upon an extension of spindle 20 is a friction disc 21, driven by the friction blocks 22, fixed upon the pivoted arms 23, which are attached to the motor-driven spindle 24. This spindle rotates the feed wheel 19 at approximately the same rate as the feed wheel of the transmitter. For adjusting the driving tension the spring 25 is arranged to slide longitudinally on the rods 23.

The action of the machine is as follows: A line "marking" current in the relay coils moves the armature *b* to the right, causing the tongue 1 to move the valve sharply to the left. The piston 3a of the relay engine is thus caused to move to the right, and the valve of the main engine in the opposite direction. This causes the main piston to be driven to the right. The movement is transmitted by means of the bell crank 7 and the link 30 to the bell crank 8, which in turn causes the left-hand striker 13 to thrust the tooth of rod 14 between the teeth of the wheel 17, adjusting, if necessary, the position of the feed wheel, and forcing the corresponding punch 15 through the tape 18. The appet piece 31 formed on the link 30 now comes in contact with the striker, forcing it from the rod and punch, and permitting them to spring back to their normal position. On the reversal of the line current the relay tongue is moved in the opposite direction, causing a reversal of the engine, when another operation similar to that described is performed by the right-hand striker 12 upon the right-hand correcting rod and punch.

A diagramatic explanation of the action of the Creed printer is shown in Fig. 5. The received perforated slip is passed into the machine and out at B, while the slip on which the printing takes place is drawn by a pair of feed rollers on the upper left-hand side, be-

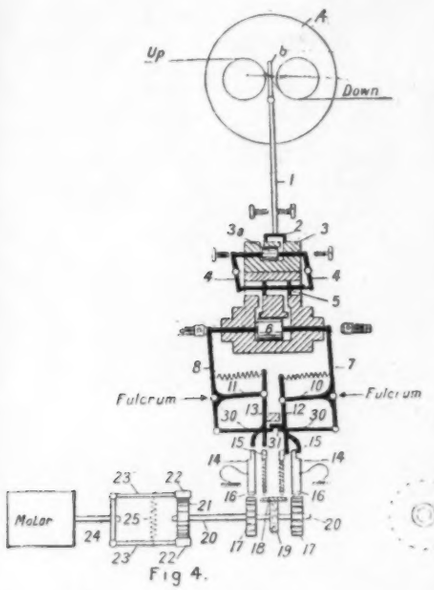


Fig 4.

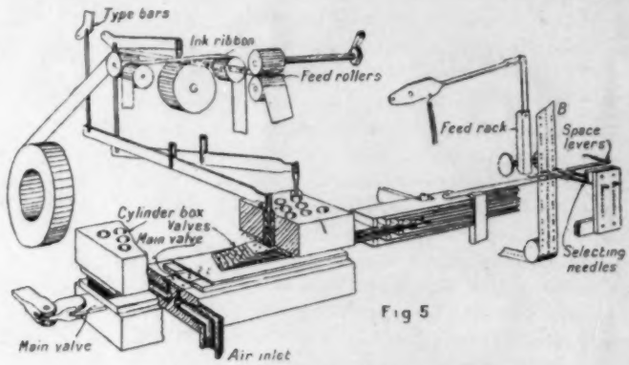


Fig 5

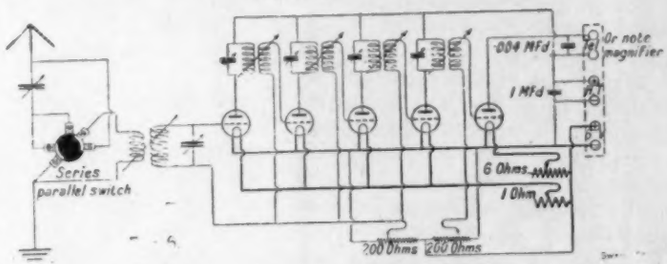


Fig. 4—Diagram Illustrating Creed Receiver. Fig. 5—Diagram Illustrating Creed Printer. Fig. 6—Sullivan Short Wave Receiver and Amplifier.

tween the connecting-rods of the type-bars and over the printing plate.

The perforated tape is fed forward letter by letter in a guide-way in front a series of ten pairs of selecting needles, one needle of each pair being mechanically connected to a series of ten slide valve plates. Each of these valve plates can be made to occupy one of two positions, thus providing a number of different combinations, every one of which opens one complete and particular passage through the ten slide valve plates. Air under pressure can thus be admitted to any one of a number of small cylinders, each containing a piston acting the end of a lever connected to a type bar, there being just as many cylinders as there are different characters and figures to be printed.

The perforated slip is fed forward by a star wheel fitted to spindle carrying a toothed wheel, which is rotated as required by the movement of the rack. The rack is given a vertical motion for feeding purposes, and a sidewise motion for acting on any slide valves that may have been selected. Its movement is obtained from the cam shaft of the machine, which is belt-driven from a small electric motor. The extent of the vertical motion is limited by the distance to the first space signal, that is to say, the length of a letter. To provide for this limit there is a group of ten space levers normally in the path of the rack, and preventing its downward movement. Hence, with any letter or figure of the international Morse code there is clear downward path for the feed rack until it reaches a space signal. A sidewise movement is then given to the rack, putting it in gear with the toothed wheel. Next, the rack is given an upward motion, causing the toothed wheel to turn and the perforated tape to be fed upward by the amount of the particular letter that has just passed. The rack is then moved sideways again, clear of the toothed wheel, ready to descend as far as the next space signal.

The slide valves, made of thin sheet steel, have each a hinged extension whose further end is arranged to take up the movement of the corresponding selecting needle in its motion to and the perforated tape. At the same time, the extension is free to move in a direction at right angles to the needle. Each valve extension is provided with a shoulder which comes into the sidewise path of the feed rack when that particular extension has been selected. At the correct moment, determined by the position of a cam on the main spindle, the rack is moved sidewise, and engaged with the shoulders of the valve extensions which have been selected, moves the corresponding slide valves into their second position. Another cam opens a main valve, admitting air under pressure to the slide valve chamber, whence it passes through the ten valve plates by the one hole available in that particular setting of the valves, forces up the particular piston and prints the corresponding letter. Another main valve is then opened to allow the air to escape, and the second slide valves are returned to their normal position.

Although more than the required number of selecting needles for any particular letter may pass through the tape, only the proper number of slide valves are acted upon by the rack, on account of the spacing lever preventing

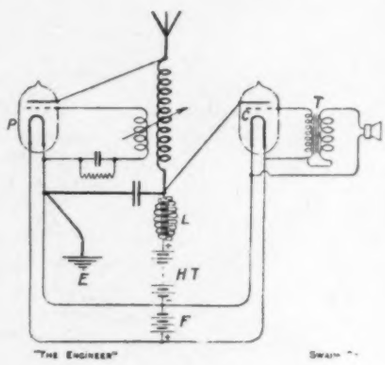


Fig. 7—Wireless Telephone Transmitter.

the rack descending beyond the required amount.

It will be observed that there are twenty selecting needles, but only the ten acting on the lower row of holes in the perforated slip are attached to valves; the other row of needles is not necessary for selecting purposes, but is required for shifting the spacing levers for the first portion of a dash signal. This instrument is by no means easy either to explain or to understand, but in its main features it is not unlike an ordinary typewriter in which the printing levers, instead of being actuated by the fingers of an individual, are each connected with the piston of a separate small pneumatic cylinder. There are as many cylinders and pistons as there are characters to be printed, and the wonderful part of the mechanism is that whereby the cylinder connected with any particular letter that has to be printed is connected to the air supply at the right moment.

This is effected by the sliding perforated plates which constitute a very elaborate form of multiplex slide valve controlling the access of air to the whole of the cylinders, but admitting the pressure to only one cylinder at a time. The motion of these sliding plates are in turn controlled by the little pins which are all the time feeling for the holes in the perforated tape as it passes by, and working in and out of these holes. It is a very remarkable arrangement, for it is an apparatus with a memory. For instance, if three dots come along on the tape, it prints the letter "S." If, however, it gets a further signal beyond these three dots, it has to remember these three dots while it is waiting to see what is the nature of the additional signal. If the latter is a fourth dot, it then prints the letter "H," but if the last signal is a dash then it prints the letter "V." Thus for any letter or figure that is denoted in the Morse alphabet by more than a single signal, the machine has got to remember the nature of all the signals it has accumulated for that particular letter before it knows what letter to print.

Having described the instruments, Mr. Campbell Swinton then proceeded to adjust them so as to receive messages specially dispatched from the Admiralty station at Horsea, near Portsmouth, and from the Eiffel tower. The latter, which, it was explained, was sent on a 2600 m. wave, was as follows:—"FL FL. This message is sent by permission of General Ferrie by automatic perforated tape wireless transmitter from the Eiffel Tower, Paris, for the purpose of being recorded on a Creed type-printing receiver at a meeting of the Royal Society of Arts on the occasion of an address on Wireless Telegraphy by Mr. A. A. Campbell Swinton, November, 1920. FL FL." Both messages were printed in Roman characters. The author then went on as follows:

We will now pass on to another and entirely different branch of my subject, namely, Wireless Telephony, of which we hope to show you a practical demonstration from a private wireless station at a distance from this hall. In doing this we are restricted by the regulations under which the authorities limit unofficial wireless transmission to the very short wave length of 180 m. and the exceedingly small power of 10 watts. These restrictions add greatly to the difficulty of getting good results, but we will see what we can do. Fig. 7 shows diagrammatically the connections at the transmitting station. In order to produce the necessary electro-magnetic waves, we employ two oscillating thermionic valves very similar to those that I have described to you in connection with receiving amplifiers. In the figure, P is the power valve, while *c* is the control valve connected with the telephonic microphone on the right through the transformer T. The aerial is shown at the top of the figure, and

it will be seen that the plate electrodes of both valves draw their high-tension supply of electricity through the choking coil L from the 400-volt dry battery H T, while the 6-volt accumulator F supplies current for the filaments. The whole arrangement is one of the forms of wireless telephone transmitter employed by the Royal Air Force.

Coming now to the receiving apparatus in this room, we are going to employ a short wave length five-valve amplifier which has been made for me by Mr. Sullivan, specially for this meeting. The connections are shown in Fig. 6, and as you will observe, the connection between the adjacent valves is made by means of transformers, as was the case in the three-valve amplifier that I have previously described. In this case, however, the transformers have no iron cores, and are specially designed to suit the short wave length. In addition, the primary of each of these transformers is fitted with a separate adjustable condenser by which it can individually be tuned. There are also two potentiometers for the purpose of regulating the grid voltage on the last two valves, while the current through the filaments of the first four valves can be regulated separately from that through the filament of the last valve. In connection with the aerial on the left-hand side of the figure there is a series parallel switch by which the primary tuning condenser can be put either in parallel with, or in series with, the aerial.

A demonstration of wireless telephony was then given, several messages being received and made audible to the audience. In addition, there were two recitations and an exhibition of wireless whistling. Finally, some music from a gramophone was received, and the author went on to say:

With regard to the wireless transmission of speech and music such as you have just heard, I should like to say that while it is not difficult to get speech and music very distinctly reproduced in a telephone receiver such as you hold to your ear, it is by no means easy to magnify such sounds so as to make them loud enough to be heard distinctly all over a room such as this. With present arrangements, much magnification almost invariably leads to deterioration in the quality of the sounds, and particularly in the distinctness of the articulation. Here, then, I think there is great room for further investigation and improvement, so that large audiences may be able to hear the spoken word from a distance, wirelessly conveyed, with the same ease as were the speaker actually present in the room. For such a purpose, instruments such as the Parsons Auxetophone and the very loud-speaking telephonic apparatus of the Western Electric Company are arrangements which, I think, might be adapted to wireless telephonic transmission.

After briefly describing both these instruments, the author continued: Anyway, however exactly it may be brought about, I have little doubt that, with further experiment, it will eventually be found possible to reproduce wirelessly transmitted speech with sufficient loudness and sufficient fidelity to the original, that verbal oratory will no longer be confined, as at present, to single rooms or halls. Thus, individual speakers will be able to address an unlimited number of audiences simultaneously. Indeed, at election times, we shall doubtless, before long, see the great party leaders addressing hundreds or maybe thousands of separate meetings distributed over the whole country at once. Different political parties will have to be allotted different wave lengths, so as to avoid a babel of opposing declamations, or the distressing possibility of an audience getting a speech of the wrong political flavor, and of having perhaps the most violent Bolshevist doctrines thrust upon it just at the moment that it was expecting the enunciation of the latest conservative principles.

Another's 'Phone

[From a volume of French dialect verse entitled "Oup in Ole Vermont," by Mary Elkins Gardyne, published by Richard G. Badger, Boston. Copyright, 1920, by Mary Elkins Gardyne.]

De musique me, I lak so well,
  Dat's playin' nace an' sweet,
An' we'en I hear de violin
  I can't kip still ma feet.
Som' tank victrola ees de bes',
  Dem beeg bug, piano;
W'en Camille she com' off de state
  Her have de piccolo.
Dere's beeg pipe organ on de church
  Dat hev'ry wick we hear,
Mais you jos bet eet ain't de wan
  Dat geev me mos' plaisir.
Down to de Fair we go en Fall
  To hear de brass-ban' play.
An' dat leetle "Marie-go-'roun' "
  Mak' musique all de day!
I say "Ba out, dat's purty good,"
  An' all my monee go.
So young wan ain't get troo de place
  On all de leetle show.
Mais, jos de sam,' w'at beat dem all
  W'en I am home alone
Ees leetle bell dat ring all tam
  Since Antoine got de 'phone.
We got nace place out troo de wood,
  Oup on de hill she stan.'
We buy eet cheap becos ennui
  Ain't 'gree wit' Yankee man.
Dat R.F.D. don' pass de door—
  De box a mile away—
So on de house we do not get
  De mail—not hever day.
Mais, since dem boy was on de War
  Dat bell ring more an' more,
An' som' beeg lady talk to me
  Dat nevaire spik before,
An' tole me dat de paper say
  How Paul stan' by de gun,
An' ain't afraid for tak' hees chance
  To mak' de German run.
I knit de sweater, sock also,
  Mais, how de Red Cross known
Dat I was firs' class on de job
  Hif Antoine ain't de 'phone?
De Cure call us for de Mass
  He say for Jean Lemay.
Her t'ree year dead, but jos de sam'
  Eet halp her hif we pray.
De teacher let de yong wan know
  W'en school don' kip som' more
So de don' walk t'ree mile to fin'
  A note pin on de door.
We user wish for educate,
  But wit' de 'phone so near,
You all right hif you cannot read
  So long as you can hear.
Dere's plaintee say eet on de 'phone
  Day don' say on de face,
Ba, hif you listen you fin' out
  W'at's goin' roun' de place.
For w'en I hear dem call Docteur
  I go me right off quick.
P'rap dey need me for de work
  Hif dere was som' wan sick.
Dere's Madame Smiff who brag an' tole
  How soon hees washin's done,
So I 'phone down to next nabor
  An' fin' he ain't begun.
An' don't forget I let heem know
  De mo's firs' chance I had,
Mais now he don' say quite so moche.
  Heem ain't wan half so bad.
W'en som' wan 'phone to make visite
  I've plaintee me for heat,
An' feex de w'ole house all aroun'
  Dey mos' slip oup deir feet.
Mebbe you t'ink la bella maison
  Ees w'at mak' me happy,
Wit' ronnin' water en kitchen
  An' firs' class galerie.
Mais dis ees true, dat ain't de t'ing
  Dat geev de place de tone,
Eet's musique I hear, all de tam,
  Since Antoine got de 'phone!

* * *

Arthur's Business Head

When little Arthur asked his mother what prayers are he was told that "Prayers are messages to God."

"Oh, I see," said little Arthur. "And we wait until bedtime to send them so's to get the night rates."

The Problem of Telephone Service

A Paper Presented at the Recent Springfield Convention of the Illinois Independent Telephone Association

By H. D. CURRIER
Chief Engineer, Kellogg Switchboard & Supply Co.

H. D. Currier.

THE word "service" as used in connection with a public utility may mean anything. In the mind of the subscriber, or user of the service, it may mean one thing, and as reflected from the endeavor of the public utility company it may mean another.

The subscriber, or user of the service, does not offer his definition of service in any other way than the reflection of satisfaction or dissatisfaction.

The public utility company may indicate its understanding of service in many ways. If the public utility company is guided by the conclusions of one man, the service rendered may not be sufficient to satisfy the minds of the subscriber or user. If a number of men are involved in formulating the service rendered, it may come near the point of satisfaction of the subscriber or user.

Where technical knowledge is properly co-ordinated with good business management, the service is usually good. Where the service is rendered with a full understanding of the public's requirements, combined with proper business and technical knowledge, the service is still better.

This brings up the question: What are the public's requirements? We know the public is likely to require anything, if it is not properly educated as to the limits of accomplishments. It, therefore, seems necessary that the public utility company keep the public informed as to the limits of accomplishment possible, commensurate with available revenue.

The technical branch of a public utility company should keep the business part of the organization informed as to what these limits are, and, in turn, should inform the public what rates are necessary, in order to render the best possible service, and the public should pay these rates.

In order to do all these things, and see that the public utility company and the public fulfill their obligations, we have caused to be organized the public utility commissions in the various states.

We have said it is the duty of the public utility company to keep the public informed as to the limits of accomplishment commensurate with available revenue. If this is true, it is the duty of the people in the public utility business to keep commissions advised as to what accomplishments are available for the public, providing the rates are forthcoming to render these accomplishments.

In our work of rendering service in the telephone business, we have covered a great deal of ground in a comparatively short time. The art of telephony is highly complicated—at least we have made it so. Commissions have not received from us the help to which they are entitled. When called upon to supply them with knowledge of the business we are in, we give them an answer embellished with involved data and so-called scientific facts, which are of slight value to them in arriving at conclusions.

The results of all this is that our copyrates are largely determined on basis of physical valuation, and we occupy a position in relation to the public the same as the coal merchant or any other dealer in staple articles.

The service we render in the telephone industry is unlike any other public utility. In our business we have not had a yardstick by which our endeavor was measured. Electric power has the unit of watts; gas can be measured in feet; transportation is reduced to the cost per car mile. The telephone has developed in its use so that it is part of our very selves.

The first conception of what a telephone was supposed to accomplish was that it permitted two people to talk to each other from a distance. If it fulfilled that purpose in the early days, the public was satisfied. Today, that accomplishment is taken for granted and service complaints are mostly founded on the delay in establishing connections, reliability of connections, failure to ring the called party, inability to initiate a second call and, in some cases, lack of courteous treatment.

The temperature of the user of a telephone is involved in rendering service. What other public utility can you find in which human temperament plays such an important part? Our commissions cannot deal with this question of temperament by handing the public a lot of technical data. They cannot soothe the passions of an irate subscriber by handing him a long tabulation on physical valuation.

They can, however, deal with this element of human temperament, if they have a code of accomplishments at their disposal to refer to and determine whether the conditions involving the rendering of service are in accord with the fundamentals of good practice.

We have spent years in this industry arguing among ourselves regarding our individual conception as to system of operating. The long-haired and wild-eyed inventors have preached their wares. The business man has not had time nor inclination to go into the details of design. He has worn himself out trying to deal with the public, using the tools the engineer has placed at his disposal. The commissions have tried to find some line of logic which would apply to the temperament of the subscriber, the business conception of the management and engineering data.

None of these perspections, taken alone, can guide commissions in arriving at the answer of rates and service.

What we need in our business is a lot of expert subscribers. By that I mean we should step out of our positions as expert telephone men, and, with our knowledge of the art, assume for the time the attitude of a subscriber. We have all done this at times. We all use telephones and pay for them. Our temperament has been reflected in the experiences we have gone through

when things did not go right. We have formed our opinions of how good or how bad telephone service was. We have never gotten together as subscribers but always as expert telephone men.

The subscriber supports the industry. If all our subscribers knew what was possible or impossible in this business, we would be told what to render in accomplishment through our commissions. If our subscribers knew what is in the storehouse of telephony, the arguments as to specific means of accomplishment would end and our commissions would judge service on a basis of the rendition of these accomplishments at the lowest annual charge per station.

Service as reflected in the mind of the subscriber is largely controlled by the central office equipment. The temperament of the subscriber is affected by the performance of the variable elements of the plant. Poles, wire, conduit, cable, etc., are what might be termed fixed elements. The variable happening in the central office must meet the variable temperament of the subscriber. Proper design of central office equipment should meet the impatient temperament of the subscriber.

Satisfaction should be conveyed to the subscriber, not by inviting him to come to our telephone exchange, and showing him the "wonderful complex" equipment which he does not understand, but the performance of our equipment should render an effect upon our subscriber, let him call it what he will, which will make it unnecessary for us to overawe him with our display.

If we become expert subscribers, what can we say we are entitled to in the way of accomplishment?

A service committee in Wisconsin has said the following: A subscriber is entitled to: 1. Fast answer; 2. Reliable connection; 3. Notification that the call is being taken care of; 4. Good transmission; 5. Prompt disconnect after conversation is completed; 6. Non-interference in communication; and 7. Courteous treatment.

What definitions of accomplishment have we available in the art of telephony which will meet these requirements?

Under the heading of a "fast answer" we can say that the application of the known principle of "call distribution" will produce this result. We could eliminate call distribution and substitute "operator distribution" and produce the same result.

Whether we use "call distribution" or "operator distribution" should not be made the subject of a technical argument but should be determined firstly on the basis as to whether a subscriber is entitled to a fast answer, and then the commission should order it done on a basis of lowest annual charges per station.

A reliable connection is a condition largely concerned with proper supervision and maintenance. This requirement has always been met by operating companies by the proper maintenance of equipment regardless of design.

Notification that the call is being taken care of has been met by introduction of revertive ringing tone and forms part of every up-to-date installation regardless of design. The revertive ringing tone in combination with machine-ringing produces satisfaction to the calling subscriber, in that he knows the called party is being rung, and the called party is caused to answer sooner.

Good transmission is the first requirement our subscribers demand, and I think it is the present-day endeavor of most companies to give good transmission. If good transmission is not rendered, we know it can and should be accomplished.

Prompt disconnect after conversation is completed can be given by the use of modern apparatus. A subscriber should not be dependent upon the inclination of an operator to disconnect his line in a common battery exchange. This accomplishment should be performed in the functioning of the equipment.

Non-interference in communication is, of course, an obvious requirement of good service and can be given by the introduction of secret service design.

Courteous treatment is not only to be expected in the telephone business but in all walks of life.

Considering the foreging things a subscriber has a right to expect, and translating these demands into a definitial code, we can say if a central office equipment, regardless of its specific design, rendered the following accomplishments, the subscriber would receive what he has a right to expect: 1. Distribution of calls, traffic and load; 2. Instantaneous listening; 3. Machine ringing; 4. Revertive ringing tone; 5. Instantaneous disconnect; 6. Instantaneous recall; 7. Ringing control; 8. Dark keyshelf for manual boards; 9. Automatic peg count; and 10. Secret service.

The expert subscriber would want to know whether he is being served with the foregoing accomplishments.

The commissions are entitled to know how these things can be done—can they be rendered by rehabilitation methods? To do these things, are we going to involve conditions of financial hardship on the operating companies and the public?

These things can be accomplished by rehabilitation methods and, when applied, it has been the experience of the writer that the economies effected in all cases permitted of a sufficient saving in operating costs to pay the interest on the required investment and provide a sinking fund.

At this point it might be well to draw attention to the fact that the public should be made to pay rates to support good telephone service. The commissions should determine rates not only on a physical valuation, but should exercise the prerogative of their office to reward merit. It is hoped the ritual of accomplishment we are discussing may stimulate our commissions to take into account the elements of service in fixing rates.

It is hoped the consideration of service and the inclination of the public utility company to render service will cause commissions to grant rates which will let them live.

Telephone companies should not be penalized for being in business, and this is what results when rates for service are based upon physical valuation. We should sell our wares to the public through our commissions. The only thing we are selling is service, but if we cannot reduce the word "service" to a tangible definition and understandable language, we cannot expect to collect on it.

The element of a plant which has most to do with the subscriber's temperament and his understanding of service, represents the smaller portion of the physical valuation of the plant.

A valuation can be shown in a set-up of data before a commission, the buildings can be modern and the outside plant in 100 percent physical condition, yet the service rendered can be poor. A rate could be granted and the public protest on the payment of this rate. The outside plant could be in a poor condition, yet, if continuity of conductors was present and the telephone building was in a dilapidated state, the public would not protest the same rate, if service under the foregoing definitions was being rendered.

The telephone company with the 100 percent outside plant and modern building can get the rate today, for the courts have held that they can collect on proven investment, but the company with the poor outside plant and buildings, yet with a pleased public, cannot get the rate which will enable it to place its property in a good physical condition.

This statement is not made in criticism of commissions. They are working with all the tools we have given them to use. If we get behind the word "service," tell our commissions what it means, give them a measure by which they can determine our worth, we may be able not only with them, but with

our public, to so present our case that we can prosper and be rewarded for our endeavor.

The code of accomplishments outlined were written with the single-office common battery exchange in mind. The statement as to what our expert subscriber would say he had a right to expect, is applicable to any exchange from the smallest rural plant to a multi-office district.

The time available does not permit going into detail as to how these various accomplishments can be rendered. The most economical and practical way of accomplishment should be the subject of discussion before the men employed in the technical branch of our business.

Conventions are mostly attended by managers—the business part of our industry. What you men are interested in, from the standpoint of service, is how can you sell it and make your business a success.

It is the job of the technical man to throw aside his scientific perspective and blend some business sense into his endeavor; instead of designing around a conceptive of mechanics and physics, he must go outside, out where the money comes from which pays his salary.

Do any of you realize that there is not a university in the world where a man can take a course in telephony and come out qualified to design a plant? Is it any wonder our business has been handicapped when we, ourselves, have not today a fixed code of accomplishments to which we should strive?

Today, we are in the formulation period of a mighty industry. Until we know what we are shooting at in the way of service, we will never produce the most economic and efficient design to render service.

The accomplishments outlined are not original with the writer. They are nothing but tabulations of things that the history of our business has disclosed as possible. The future may add to the list. So long as we design around that which has been disclosed as possible, we can safely say we are doing our part. The facts of our business as regards service have been referred to as follows:

"The conduct of people in relation to each other and the rule, called laws, governing these relations passed through several stages of development.

"There were various codes in use, and each code had some good in it. The man who attempted to master the reasoning of these various codes found them tucked away in musty files and legal recesses, until Blackstone went to work and filtered out a comprehensive reasoning basis for study.

"The telephone industry today is conducted by various codes of reasoning, and just as the various laws of the past were ultimately worked out by Blackstone, sooner or later the things governing telephone service have got to be Blackstonized."

We might add to this statement the fact that as the common laws of our country are founded upon the filtered reasoning of the people of the past, so will the future definition of telephone service be the filtered appreciation of our subscribers in a definitional form and not in the design form of the engineer.

The word "serve" is defined as follows: "Work for; aid, obey; suffice."

Applying these definitions to the business we are in, we can say the public utility company "works for" the public. We "aid" the public, for which we should be paid, in building the structure of social and civic relations of which we are all part. We should "obey" the fundamental laws of constructiveness, which have been written into our sciences and codes of equitable relations so that our endeavors may "suffice" to qualify us as having carried on our work, that it may rest in the knowledge of mankind in the form, and understanding it should have, to the other branches of human progress.

And we must have a commission to see that we do a good job of giving service, and when we give service they should take it into account in making a rate.

New York Association Organized

At a meeting held in the office of the Rochester Telephone Company recently an organization to be known as the Up-State Telephone Association of New York was launched.

At the meeting companies operating more than 150,000 telephones were represented.

The meeting organized by electing George R. Fuller, president of the Rochester Telephone Company, as chairman, and G. G. W. Green of the Glen Telephone Company of Johnstown, as recording secretary. Mr. Fuller was afterward elected president of the new association. The meeting elected Bert H. Shepard of Syracuse, as first vice-president; J. G. Ihmsen of Buffalo, as secretary and manager, and C. M. Beattle, treasurer of the Rochester Telephone Company, as treasurer.

The following were elected directors and district vice-presidents: Bert H. Shepard of Syracuse, representing Eastern Central New York; John H. Wright, Jamestown, Southwestern New York; H. W. Fincher, Oneonta, Southern New York; H. P. McDonough, Newark, Western Central New York; J. P. Boylan, Plattsburg, Northeastern New York; F. D. Fancher, Middletown, Southeastern New York; G. G. W. Green, Johnstown, Eastern New York; F. S. Rodenhurst, Clayton, Northern New York; C. M. Smith, Perry, Western New York, together with Mr. Fuller, president of the association.

An executive committee was also provided for, consisting of B. H. Shepard, F. D. Fancher, G. G. W. Green, H. P. McDonough and John H. Wright, with Mr Fuller, ex-officio.

Loud Speaking Devices for Nursery

Unless scientific progress declares a halt soon, there will be little respite for the parents of the next decade. The day when the proud fathers could hide their heads under the covers those winter nights and console themselves with the thought that a little squawking would work to the vocal advantage of their young hopefuls, is no more. P. A. Curry, an inventive citizen of Baker, Ore., has come to the aid of the neglected infants.

Mr. Curry is a father who takes his state with a certain sense of responsibility. Not long ago he attended a demonstration of the latest developments in the electrical world. A few days later he communicated with the office of the Western Electric Company at Portland, Ore., requesting full information on the loud speaker, the magnifying apparatus which has been used recently to carry the voice at the big conventions and meetings throughout the country.

It happens that Curry, the younger, sleeps in the porch nursery. His biggest source of complaint is the fact that on several occasions he has had to do without company in the wee small hours because his cries were unheard by his sire. This calamity is to be relieved. Curry the senior, has made plans to wire the nursery. Three loud speaking transmitters will be installed over the infants' bed connecting with a receiver over that of his father.

In the future instead of being compelled to sleep with one ear open awaiting a summons from the nursery, pater familias can rest content, assured that he will be awakened by an unearthly shout every time his infant charge sees fit to announce his awakening.

Several engineers of the bachelor class who have been consulted on this unique addition to nursery accessories have suggested that a muffler instead of a loud speaking device would be more in keeping with peace and order.

Minimizing Inductive Interference

A Paper Presented at the Recent Convention of the Illinois Independent Telephone Association at Springfield

By J. G. WRAY and CYRUS G. HILL

INDUCTIVE interference is the designation applied to electromagnetic induction when the property of electricity instead of being the servant which runs our machinery, goes wrong and plays havoc with our telephone circuits. Electromagnetic induction, the laws of which were unraveled by Faraday, may be illustrated, experimentally, as follows:

Two circuits, A and B, Fig. 1, are placed near together, but completely isolated from each other. Circuit B contains a galvanometer and circuit A a battery and key. Supposing circuit

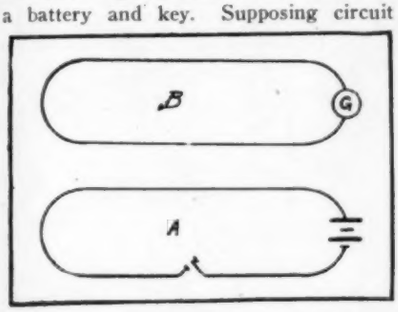


Fig. 1. Two Parallel Untransposed Circuits.

A, at the beginning of the experiment, to be interrupted, press down the key and close the circuit. The galvanometer in B will be momentarily deflected, indicating the passage of a current through B, although it is completely insulated from the battery.

The deflection of the magnet of the galvanometer in B indicates that an electromotive force of very short duration has acted around B, producing a current in a direction opposite to that started in A. After the motion of the magnet subsides, it will remain at rest although current continues to flow through A.

If we raise the key in A so as to stop the current flowing through the circuit, the galvanometer in B is again deflected, the direction of the first swing in this case being opposite to that which occurred upon starting the current in A, indicating an electromotive force around B, tending to start a current through B in the same direction as that which previously existed in A.

This experiment shows that the starting or stopping of the current in circuit A is accompanied by the production of another current in a neighboring circuit, B, the current in B being in the opposite direction to that in A when the current is started, and in the same direction when the current is stopped.

Now twist circuit B one-half turn to form a figure 8, as shown in Fig. 2, the loops on each side of the mid-point being equal. Closing and opening circuit A by means of the key will now produce no deflection of the galvanometer in circuit B, since equal and opposite electromotive forces are produced in the two halves of circuit B. In this experiment we have a simple illustration of inductive interference on telephone circuits and the effect of transposition, Fig. 1 representing two parallel untransposed circuits, and Fig. 2 two parallel circuits, one of which has been properly transposed to reduce effects of induction.

Before the days of general distribution of electric power over long distances at high voltages, a development of the last 15 years, telephone interference troubles were limited largely to induction between telephone circuits on the same lead. This difficulty, known as cross talk, was overcome in the case of metallic circuits by transposing the circuits in such a way that within each eight-mile length or less, each circuit inducted approximately equal and opposite voltages and currents in every other circuit.

The problem of eliminating cross talk on open wire lines has been so completely solved and the most effective arrangements of transposition so standardized, that the constructor of a telephone line has but to choose from diagrams of many transposition systems, those which best meet his requirements as to number of wires, grouping phantom circuits, and distances between points of discontinuity.

In dealing with the inductive effects of power lines upon telephone circuits, the problem is complicated by the replacement of small, well-balanced telephone currents by power voltages and currents which are not only usually unbalanced, but of such magnitude that the effects of small unbalances in the telephone circuits are magnified. The voltages or currents of a power line are balanced if the Vector sum of the voltages or currents in all wires of the circuit at any point at the same instant is zero.

By a well-balanced telephone circuit is meant one in which the series impedances of the two line wires are nearly equal and the admittances to ground of the two sides of the circuit are approximately the same at every point. Theoretically, a perfectly balanced telephone circuit would be noiseless, no matter what voltages to ground were induced by neighboring power lines, since the voltages on the two telephone wires would everywhere be the same and there would be no tendency for current to flow between wires through the telephone receiver.

Although it is impossible to obtain a perfectly balanced telephone circuit, careful maintenance and the use of modern standard apparatus on a metallic circuit will give a sufficiently high degree of balance to reduce noise except under very severe conditions of outside induction.

In the treatment of the noise on metallic circuits, due to induction from power lines, the first consideration is, therefore, the balance of the telephone circuit.

Impedance unbalance may be caused by any of the following troubles: Defective or poorly designed central office apparatus; high-contact resistance in test connectors; bad joints in wires, particularly iron wires.

Admittance unbalances are usually due to defective or broken insulators, contact of line wires with trees, leakage at open-space cut-outs in cable boxes or in central office, cable lengths having capacity or insulation unbalances between cable conductors and ground.

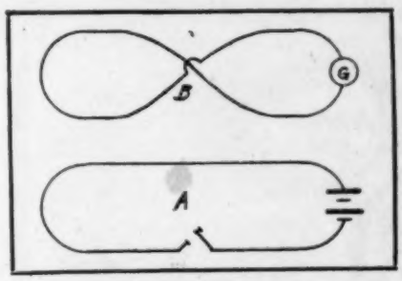


Fig. 2. Two Parallel Circuits, One of Which Has Been Properly Transposed.

The location and correction of such defects is a part of the regular maintenance routine of a well-maintained telephone plant and need not be described in detail here. In investigating noise, however, a simple method of determining whether the excessive interference is due to an unbalanced condition of the telephone line or to high induction from external sources is desirable.

Such an easily applicable test is suggested by the fact that, if the telephone circuit is well balanced, the noise produced in a telephone receiver be-

tween the line wires and ground will be very much greater than the noise when the receiver is connected between the two sides of the circuit, whereas on a poorly balanced line these two amounts of noise will be more nearly equal. The ear unassisted is a poor judge of relative amounts of noise.

To put the observations on a scientific basis, we may either insert artificial cable in series with the receiver until the noise ceases to be heard, calling the number of miles of cable inserted the measure of the noise, or we may compare the line noise with an adjustable standard of noise on which a reading can be taken when the two sounds are in the judgment of the observer equal in intensity.

The difficulty with the artificial cable method is that since ears differ in acuteness, no two observers will get the same answer. The better method is, therefore, to use a standard source of noise across the terminals of which are connected a receiver and a variable shunt for adjusting the noise heard in the receiver to equality with the noise in the same receiver when connected to the line.

A satisfactory type of portable noise standard consists essentially of dry cells operating a carefully adjusted vibrator having two windings, the primary winding being connected to the battery, and the secondary winding to the telephone receiver and shunt.

The arrangement of apparatus and connections for making noise tests are shown in Fig. 3. A double-pole, double-throw switch will suffice to connect the receiver, first to the line under test, and then to the shunt, in order that comparisons may be made. A 100,000-ohm lavite resistance is usually required in series with the receiver, when measuring induction to ground, in order to obtain a reading within the scale of the variable shunt.

A type of rheostat frequently used as a shunt consists of a box containing a set of resistances connected to contact terminals, and so arranged that when a wiper stands over a given contact, the reading corresponding with that contact will represent numerically that fraction of the total current flowing through the rheostat which passes through the telephone receiver. The unit for the measurement of noise then will be the sound in the telephone receiver when a given fraction of the output of the portable noise standard passes through the telephone receiver.

For comparative readings to determine the condition of balance of a single telephone circuit, any buzzer which will maintain a fairly constant output for a few hours, and a rheostat with a range from zero to about 5,000 ohms will serve the purpose, although the readings thus obtained cannot be compared with readings obtained on other lines by the use of other apparatus. The balance of the telephone circuit is usually satisfactory if the ratio of noise between wires to noise to ground is less than unity. It may run as low as 0.5 for short sections of line.

Before making tests, the telephone circuits should be disconnected from all terminal apparatus, and if it appears that the noise caused by the power circuits under investigation is masked by noise arising from sections of the line outside the parallel, the portion, including the parallel, should be isolated by opening all the circuits of the telephone lead at the proper points.

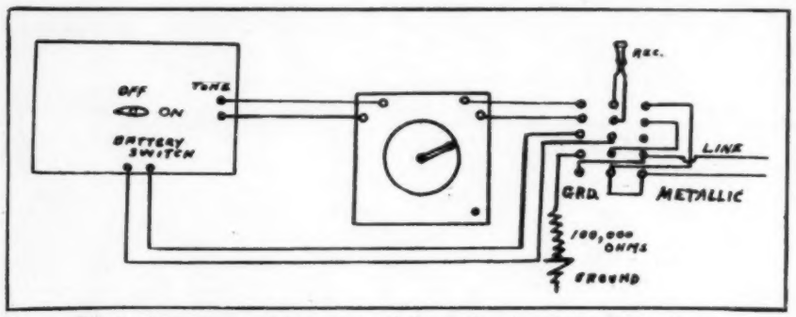


Fig. 3. Arrangement of Apparatus and Connections for Making Noise Tests.

The noise tests which it is desirable to make on telephone circuits suspected of inductive interference, and the conclusions to be deduced from the results are:

1. Noise between wires:

Line opens at the distant end; line shorted at the distant end; line looped through resistance of 1,000 ohms.

Noise between wires and ground:

Line opens at distant end; line grounded at distant end.

2. When practicable these tests should be made with:

(a) Power line shut down;

(b) Power line energized without load; or

(c) Power line in operation with normal load.

If more than one power line is involved, measure the noise with but one line at a time energized and with all of the circuits energized.

From the foregoing measurements we learn: First, whether the telephone circuit is reasonably well-balanced; second, the amount of noise caused by each power circuit; third, what part of the noise is due to the voltages and what part to the currents of the interfering system, interference from voltages being indicated by high noise readings with the telephone line open and interference from currents by high readings with the telephone line short-circuted at the distant end; and fourth, from the measurements under different load conditions, an indication of what particular machines or conditions of the power circuit are responsible for the trouble.

For the simplest exposures to induction, when both power and telephone circuits are metallic, the balance of the telephone circuit is good and the parallel is fairly uniform throughout its length, permitting the two circuits to be accurately balanced with respect to each other by means of transposition, the foregoing noise measurements, together with maps showing the location of telephone and power poles and the arrangements of conductors, will provide all the data necessary for the design of a co-ordinated system of transpositions adequate to bring inductive interference within allowable limits.

By a co-ordinated transposition scheme is meant an arrangement of transpositions both in the telephone and power circuits which will minimize the transfer to energy inductively between the two circuits. The circuits so transposed are said to be balanced with respect to each other.

It will not be possible to give here the methods of design of transpositions for parallel power and telephone circuits. This subject has been trated in considerable detail by Harold S. Osborne in a paper presented at the annual convention of the A. I. E. E. on June 27, 1918.

Co-ordinated power and telephone transpositions are, in general, the most economical and effective method of reducing inductive interference where metallic circuits are involved. The importance of this method of treatment will justify a few words in regard to the theory and its application to the simplest cases.

Fig. 4-A shows, diagrammatically, a three-phase power circuit and a single telephone circuit transposed in such a way as to be mutually balanced. Each rotation of the power wires shifts the phase of telephone induction 120 degrees so that in three sections of equal length, including two such rotations, the sum of inductive effects of the three sections

will be zero. This applies, however, to the balanced portions of the power circuit voltages and currents only—that is, to the portions which in the three wires add up Vectorally to zero.

The unbalanced or residual voltage and current, which is of considerable magnitude in most commercial, three-phase power lines, flows through the three line wires in parallel, returning via the earth. In order to balance out the

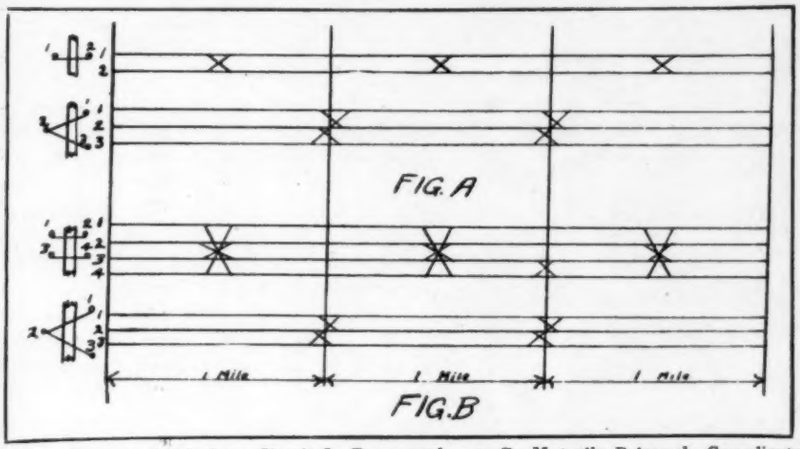


Fig. 4. Power and Telephone Circuit So Transposed as to Be Mutually Balanced—Co-ordinated Transposition Scheme for Telephone Circuit and Power Line.

inductive effects of these residuals, the telephone line is transposed at the mid-point of each untransposed section of the power line.

As the number of telephone circuits carried on the same pole line is increased the design of transpositions becomes more difficult, since it is necessary to obtain a cross-talk telephone circuit to outside induction. Fig. 4-B indicates a co-ordinated transposition system involving a telephone phantom group, or two side circuits and a phantom circuit, and a three-phase power line. In order to check the efficacy of the transposition system in producing a balance, both to power induction and cross talk, it is necessary to determine for each circuit the total length exposed to induction of a given phase, at a given separation, and the total length which will carry induction of the opposite phase at the same separation, the difference between these lengths being the equivalent unbalanced exposed of the circuit in question.

It should be observed in Fig. 4, that those components of the power voltage, of current which flow along the three wires in parallel, will induce a voltage between the two sides of the telephone circuit in parallel and ground. This is known technically as longitudinal induction from residual voltages and currents.

No transposition scheme has any effect in reducing this component of induction. Where it becomes troublesome, we must turn to the design of the power circuit for a clew to its cause and the best method of treatment.

The serious inductive interference resulting from residual voltages and currents in the power line is due to the fact that these residual components act as a single-phase circuit operating over the wires of the power circuit in parallel with a ground return. Neutralization or limitation of the electromagnetic field through the action of adjacent wires of opposite polarity is, therefore, lacking. Residual currents are particularly troublesome in this respect. It has been found that slightly unbalanced components in the power circuit may have very much greater effect in inducing currents in parallel telephone circuits than large balanced components.

In case of noise on telephone circuits of such severity that it is doubtful whether co-ordinated transpositions will cause sufficient reduction, and particularly in case of a telephone line using ground return, where transpositions of the telephone circuit are, of course, impossible, tests to determine the character and magnitude of the unbalanced currents and unbalanced voltages of the power circuit are desirable, in order to determine their cause and the possibility of reducing them by changes in the power system.

The investigation of the power circuits should include: First, a study of the general layout, operating voltage and load, the arrangement or configuration of wires, the types of machines connected to the circuit and the locations and connections of transformer banks; and second, the measurement of residual currents and voltages.

The measurement of residual current is made by placing current transformers of equal ratios in all the line wires of the power circuit and connecting the secondaries of the current transformers together in parallel through the same ammeter. The ammeter will then indicate the vector sum of the currents in the secondaries or the current transformers —that is, the residual current.

In the case of a single three-phase circuit connected to a bank of transformers having a grounded neutral, the residual current is equal to the current flowing in the neutral wire and may be measured by a single ammeter. The residual voltage is measured by means of potential transformers of equal ratio placed between all the line wires of the circuit and ground. The voltage across the secondaries of these potential transformers when connected in series through a suitable voltmeter, give a measure of the vector sum of the voltages between the several line wires and ground—that is, of the residual voltage.

Large residual currents are usually found on power circuits operated with the neutral grounded at more than one point. Unequal loading of the several phases with such an arrangement causes unbalanced load current to flow through the ground whether or not the system is provided with a neutral wire. Also, in the case of three-phase systems having transformer banks Y connected with grounded neutrals, currents of third harmonic frequency and its odd multiples, appear as residual line currents.

The best means of limiting the residual currents is usually to operate the power circuits without grounds or with the ground at one point of the system only. This reduces the current unbalance by removing the return path for currents which are in phase in the three wires, but may also increase the residual voltage, for reasons to be explained later.

When it is impracticable to remove the grounds from the power system, the unbalanced currents may be reduced by careful balancing of the load current in the various phases, and by using closed delta windings on transformer banks which provide shunt paths for the triple harmonic currents in parallel with the path through line wires and ground, thus reducing the magnitude of the unbalanced current in the line.

Residual voltages are usually caused by unbalanced leakage or capacity between the line wires and ground. Three-phase circuits with every arrangement of wires in common use, have unequal capacities between the three line wires and ground unless they are properly transposed. To reduce this unbalance, where a power line is found to carry large unbalanced voltages, all lines, which are in metallic connection between the power line involved in the parallel, should be transposed for their entire length, the transpositions outside

the limits of the parallel being such as to form barrels from six to twelve miles in length, and, within the parallel, barrels of not more than three miles.

Certain circuits are inherently unbalanced electrostatically. Among the most common of these are three-wire, two-phase circuits and three-phase circuits having two-wire simple-phase taps of unequal length taken from different phases. Single-phase circuits tapped from three-phase circuits are subjected to an impressed voltage having a phase difference of 120 degrees instead of 180 degrees between wires.

The remedy for electrostatic induction from circuits of these types lies in modification of the circuits in such a way that they can be balanced. Three-wire, two-phase systems can be changed to four-wire, two-phase systems. Three-phase systems with single-phase taps are balanced if taps of equal capacity are connected to all phases, or if transformers are inserted at the points where the taps join the three-phase line. A single-phase tap may be balanced by the insertion of a transformer between it and the three-phase line.

Mention should also be made in this connection of single-phase circuits with ground return, such as electric railways. Such circuits cause severe induction which is difficult to deal with. The most effective remedies consist usually in dividing the railway trolley, or third rail, into fairly short sections insulated from each other, and by the installation of track booster transformers, the function of which is to keep the return current in the track and prevent its spreading through the earth.

Trouble resulting from abnormal conditions on the power line, such as grounds or breakage of line wires, can be guarded against only by good construction and high factors of safety on all power apparatus and by the use of automatic mechanically interconnected disconnect switches operated by overload relays, which will open all line wires simultaneously in case of trouble on the power line.

Considerable annoyance to telephone users is often caused by the process of locating trouble on a power line by repeatedly energizing the defective circuit at short intervals of time. The adoption by power companies of a routine for locating and repairing troubles with a minimum of those operations which cause disturbing effects to parallel telephone circuits is advantageous in such cases.

In our treatment of inductive interference from power lines, we have thus far considered the relative severity of the induction arising from the various components into which it is convenient to divide the voltage and current of the power circuit. We have indicated methods of eliminating excessive noise by reducing the amount of induction in the telephone circuit, either by balancing the two circuits relatively to each other, or by removing the disturbing components of the voltages or currents.

Still another effective method of dealing with inductive interference consists in eliminating, in so far as possible, from the voltage wave those frequencies which become audible when impressed across the terminals of a telephone receiver. Frequencies from about 200 to 2,000 cycles per second are readily translated into sound by the receiver while

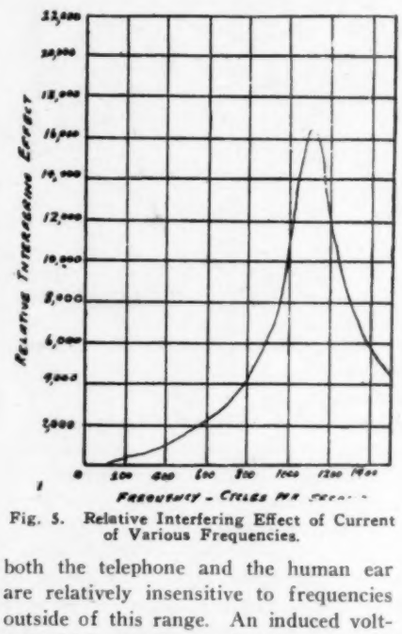


Fig. 5. Relative Interfering Effect of Current of Various Frequencies.

both the telephone and the human ear are relatively insensitive to frequencies outside of this range. An induced voltage which contains no frequencies within the audible band would, therefore, cause no noise, and would become troublesome only when its magnitude became such as to constitute a physical hazard or to operate protective apparatus.

Commercial power voltages and currents usually contain, in addition to the fundamental frequency of from 25 to 60 cycles per second, odd multiples or harmonics of the fundamental frequency from the third to the 25th or higher. Even harmonics may also appear on power circuits grounded at more than one point, due to the action of earth potentials or direct currents flowing through the earth.

Any steps tending to the reduction of the higher harmonics, which are responsible for inductive noise, must be limited to changes in the power apparatus or lines, since the removing of frequencies between 200 to 2,000 cycles from the telephone line would interfere seriously with the transmission of speech, which depends largely upon the free propagation of frequencies lying within this range.

The relative interfering effect of current of various frequencies in a telephone receiver is shown in the curve, Fig. 5, which is reproduced from the "Review of the Work of the Sub-Committee on Wave Shape Standards of the Standards Committee," by Harold S. Osborne, at the A. I. E. E. annual convention, February 20, 1919. It will be seen that interference is most acute at 1,100 cycles per second, which corresponds roughly to the 19th harmonic of a 60-cycle current.

The elimination from the power circuit of the useless and troublesome higher harmonics—in other words, the reduction of the voltage and current waves to as close an approximation of a pure sine wave as possible—constitutes a most important line of endeavor in freeing neighboring telephone circuits from inductive interference. The principal causes of irregular wave forms in power apparatus may be summarized as follows:

1. Transformers.

It has been found, experimentally, that when a sinusoidal electromotive force is applied to a single-phase transformer, the current contains a marked third harmonic and small higher harmonics from the fifth as high as the 21st. If three single-phase transformers are connected in a △ (delta) bank, the third harmonic current will circulate through the transformer windings, which form a closed circuit, and will not appear in the line current.

If the three transformers are connected in Y (star), the neutral being isolated from ground, the triple harmonic current which would be in phase in the three transformers cannot flow either through the transformer windings or in the line, since it can find no return circuit. The third harmonic will appear in this case in the electromotive force wave across each transformer and, hence, in the voltage as measured from each line wire to ground. If now the neutrals of Y banks of transformers are grounded at two or more points of the system, the third and higher harmonic currents, which are in phase in the windings of the three transformers, will flow over the line wires in parallel returning via the earth.

The conditions outlined and their results are illustrated by the oscillograms of voltages and currents in a three-phase transformer bank, shown in Fig. 6. The third and higher harmonics in the current of a transformer under a sinusoidal impressed electromotive force will be greatly exaggerated if the transformer is operated at high magnetic saturation—that is, if it is oper-

ated at voltage above those for which it is designed.

A reduction of troublesome harmonics arising from transformers connected to the power system may therefore be effected by: First, removing all grounds from the power system, with the exception of one, thus eliminating the third and higher harmonic currents; second, by operating the transformers at moderate voltages, certainly not above the normal voltage rating, thereby reducing the amplitude of harmonics in the voltage.

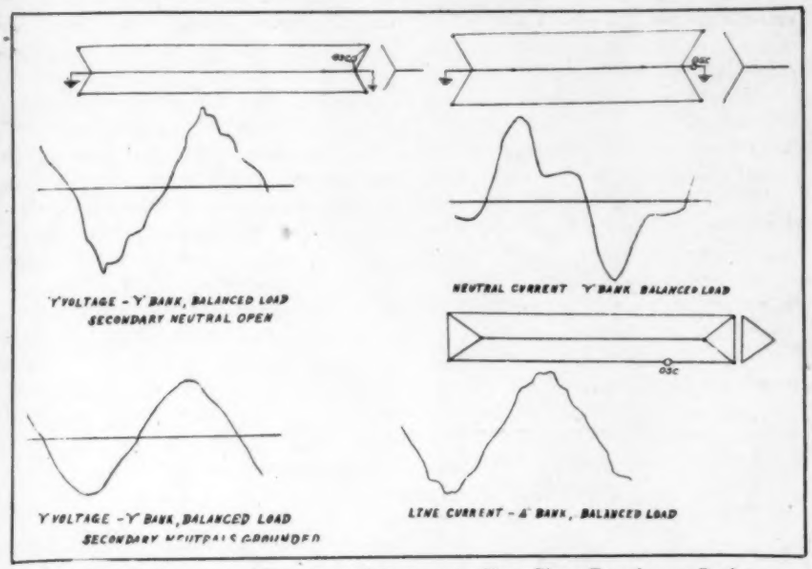

OSC
OSC
Y VOLTAGE - Y BANK, BALANCED LOAD
SECONDARY NEUTRAL OPEN
NEUTRAL CURRENT Y BANK BALANCED LOAD
OSC
Y VOLTAGE - Y BANK, BALANCED LOAD
LINE CURRENT - Δ BANK, BALANCED LOAD

Fig. 6—Oscillograms of Voltages and Currents in Three-Phase Transformer Bank.

2. The harmonics which most frequently produce inductive disturbances are those known as "slot harmonics." They are produced because in electric generating machinery the voltage is induced in an armature which, instead of being a smooth cylinder, has cut in its surface slots parallel to the axis, in which the conductors are placed. (See Fig. 7.)

The projections between these slots are called teeth and most of the magnetic flux crossing the air gap between the armature and field poles enters or leaves the armature through the teeth. As the amature rotates, the change in relative positions of the teeth and slots with respect to the poles produces a corresponding change in the position and total magnitude of the flux in the air gap.

Since the voltage across the terminals of the machine depends directly upon the magnitude of the flux threading the armature, these rapid flux variations will be accompanied by correspondingly rapid variations in terminal voltage. The frequencies of slot harmonics ordinarily range from the 11th to the 61st harmonic for a 25 or 60-cycle system.

In new machines these slot harmonics may be greatly reduced by careful design of the slots, teeth, and air gap. In existening apparatus, the more troublesome harmonics may frequently be reduced by auxiliary apparatus consisting either of series coils which offer a relatively large impedence to the flow of high frequency currents, or by shunts whose impedence is high to the working current but low to the higher frequencies.

In the study of specific cases of inductive interference, it is obviously of great importance to ascertain what frequencies are causing the most of the noise on the telephone circuit in order that the probable benefits to be derived from changes or improvements in the power system may be estimated. For this purpose, an instrument capable of measuring frequencies of telephone currents has been developed. It consists essentially of a resonant circuit containing inductance and capacity, which may be turned to the frequencies present on the telephone line by means of a variable condenser.

The sound in a telephone receiver connected to the instrument will rise to a maximum as resonance with a particular frequency is reached, will decrease as this point is reached, will again increase as resonance with another line frequency is approached. A calibration table gives the actual frequency corresponding to each setting of the variable condenser.

In this way the noise on the telephone line can be analyzed into its component frequencies, and the relative magnitude of each frequency may be determined by comparison with the noise standard by the method described earlier in this paper the frequencies traceable to each machine or transformer of the power system may be determined by using the frequency analyzer in connection with an exploring coil.

The direct dependence of the severity of telephone interference upon the wave shape of the disturbing voltage and current has led to serious consideration of the design of alternators and other electrical machinery along such lines as would minimize possible inductive interference with telephone circuits.

In 1915 a sub-committee of the standards committee of the A. I. E. E. was formed for the purpose of considering possible changes in the Institute's standardization rules regarding wave shape. The work of this committee has resulted in the proposal of a new tentative factor for the regulation of alternating current wave shape, the "Telephone Interference Factor," defined as a measure of the wave's "departure from the sinusoidal shape based upon its disturbing effects when acting inductively on other circuits."

The instrument for measuring the telephone interference factor consists of a network containing series and shunt resistance, inductance and capacity, and an indicating meter. The network is so designed as to weigh the currents of various frequencies passing through the meter in direct proportion to the disturbing effect which these frequencies cause when present in a telephone circuit.

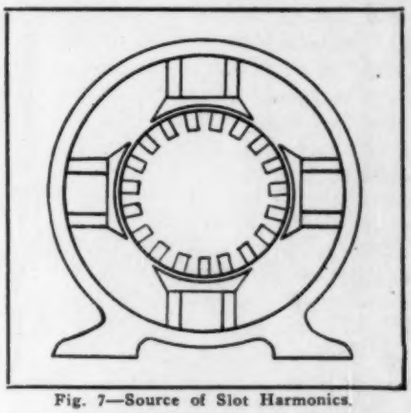


Fig. 7—Source of Slot Harmonics.

Thus the ratio of the current through the meter branch of the network to the voltage applied at the network terminals, gives a measure of the telephone interference factor. In other words, the meter indicates the weighted average of all frequencies present in the circuit, the relative weighting being carried out in accordance with a curve, Fig. 5, which shows the relative effects of the different frequencies in producing noise in a telephone receiver.

The importance of a knowledge of the telephone interference factor (T. I. F.) of the power circuit voltages in a study of the need for transpositions or other remedial measures, in particular cases of inductive interference, is evident

from the following considerations which are mentioned in the committee report.

In a high-voltage alternating-current system without neutral ground connections, the voltages are largely responsible for the noise caused in parallel telephone circuits, and the noise is approximately proportionate to the T. I. F. of the voltage wave shape. The maximum allowable length of unbalanced exposure in such cases to keep the induced noise within certain limits will vary inversely as the T. I. F. of the power circuit voltage, the separation and height above ground of the circuits remaining the same. With grounded neutral systems, the residual current is more largely responsible for noise and very little reduction may be obtained by improving the voltage wave shape.

In practice, the value of the T. I. F. for individual machines may be as low as five or as high as 500, and sufficient data has not as yet been compiled to enable us to say definitely where the dividing line between a moderate and an excessively high T. I. F. occurs.

The A. I. E. E. has requested that all those interested in inductive interference obtain the T. I. F. meter and make as complete measurements as possible on power lines and machines which are responsible for inductive interference. The results of many such observations will form the basis for the determination of a limiting value for the T. I. F. of electrical machines which are to be connected to open wire lines. The maximum permissible value of the T. I. F. will then presumably be stated as part of the A. I. E. E. standardization rules.

As an example of the method of applying the T. I. F. meter to the study of individual cases of inductive interference and its value in locating trouble and indicating a remedy, the following summary of a report on an investigation of inductive interference from street lighting circuits in a city of moderate size is given.

Measurements of noise made upon the telephone line about two weeks previous to this test had indicated severe induction arising from parallels of the telephone lines with the street lighting circuits. The object of the test here described was to determine the exact cause of the interference with a view to providing a remedy.

Current for street lighting is generated by two Allis-Chalmers horizontal turbo units, 82 amperes, 2,300 volts, two-phase, 60 cycles. The lighting circuits are supplied from five Westinghouse constant current transformers rated at 68 K. V. A., 6.6 amperes, 2,200 volts primary, 60-cycles. Each transformer has two secondary circuits.

There are ten lighting circuits, each circuit carrying approximately 120 nitrogen-filled, 15-ampere, incandescent lamps of 400 candle power. Each lamp support contains an auto-transformer or compensator for increasing the current from 6.6 amperes to 15 amperes. Only two of the ten lighting circuits are involved in the parallels which are being considered.

Since a series lighting circuits is inherently unbalanced and not adapted to transpositions, it was thought probable that interference could best be reduced by improving the wave form.

Measurements of the telephone interference factor on the generators under no load showed a T. I. F. of about 20. The generators under normal load gave approximately the same T. I. F. Measurements across the secondaries of the constant current transformers showed T. I. F.'s varying from 50 to over 600.

Since the lowest and highest values were obtained from the two secondary windings of the same constant current transformers, it was concluded that the cause of the harmonics was in the load and not in the transformers. Harmonic analysis showed the presence of practically all the odd harmonics from 3 to 21.

In order to analyze the lighting load, a single 15-ampere lamp with its transformer was connected across a 110-volt, 60-cycle current supply with a lamp bank in series by which the current could be adjusted to 6.6 amperes. Measurements of the T. I. F. of the 110-volt source gave a value of approximately 20, on open circuit. Connecting lamp transformers and lamp to the source raised this T. I. F. to about 25. The lamp was then removed from the socket, thus open-circuiting the secondary of the lamp transformer. Under this condition the measurement across the 110-volt supply showed a T. I. F. of 260 and across the primary of the lamp transformer a T. I. F. of 360.

Analysis showed practically all odd harmonics from 1 to 21 to be present.

This large distortion of the voltage wave, when passed through the primary of a lamp transformer, the secondary being open, is accounted for as follows:

The current was maintained at 6.6 amperes. With the secondary of the transformer loaded by means of the street lamp, this current was practically all load current, a small fraction only being consumed as transformer exciting current. When the lamp was removed, however, the 6.6 amperes became exciting current and the transformer was accordingly very much over excited with a resulting large distortion of the voltage wave.

The conclusion was, therefore, drawn that the high T. I. F. of the lighting circuits was due, not to the normal operation of the transformers and lamps, but to the fact that when a lamp burns out, the primary of its transformer remains in the series circuit, the transformer secondary being open.

In order to prove the conclusion that burned-out lamps were responsible for the inductive interference, an attempt was made to replace all burned-out street lamps in the city and to obtain noise measurements on the telephone lines under this condition.

The T. I. F. across the constant-current transformer secondaries was found to be almost exactly proportioned to the number of lamps which were burned out on each lighting circuit. Employes of the lighting company were then sent out to replace these lamps. With all lamps burning, the T. I. F. of each lighting circuit was reduced less than 10. At eight o'clock in the evening the test showed that all street lamps were burning At four o'clock the next morning the telephone lead was opened at a point outside the city and noise measurements were made from the test-board.

That inductive interference from the street lighting circuits had been almost entirely eliminated was indicated by the fact that there was no difference in the noise on the telephone circuits when the lighting circuits were opened or closed at the power station. Measurements of the T. I. F. of the lighting circuits showed that only a very few of the street lights were out at the time of the noise test.

The effect of opening the secondaries of two lamp transformers connected in a series with one of the lighting circuits and located in the power house was immediately indicated by increased noise on the telephone line.

The only complete cure for inductive interference from the lighting circuits seemed to be the addition to each lamp transformer of a device which will short-circuit the primary winding of the transformer when the lamp which is connected across the secondary burns out. Considerable improvement could, however, be obtained by providing for more prompt renewal of defective lamps.

The men in charge of the lighting system expressed their willingness to make replacements promptly if they were provided with means for determining the number of lamps out on each circuit. The T. I. F. meter acted as an excellent indicator of burned-out lamps and a more simple device of this kind was later made up with a sensitive voltmeter shunted by a network tuned to 60-cycle frequency.

To sum up our discussion, we have found that:

1. The balance of the telephone circuit is of primary importance in limiting interference. This is a matter of maintenance.

2. Noise tests made on the telephone line are of great value in locating the cause of interference.

3. When a co-ordinate transposition scheme can be applied to the telephone and power circuits, this method presents in a majority of cases the simplest and most economical treatment of inductive interference.

4. When co-ordinate transpositions are impossible or the induction is too severe to be cared for in this way, relief can sometimes be obtained by changes in the power system, which will.

(a). Reduce the residual current of the power circuit;

(b). Reduce the residual voltage of the power circuit; and

(c). Reduce the higher harmonic frequencies of the power voltage and current, which are the cause of noise.

5. In determining the probable effectiveness of the possible methods of treating inductive interference in particular cases, the following instruments are helpful:

(a). The frequency analyzer to determine the frequencies present, their magnitudes, and their sources; and

(b). The telephone interference factor meter to determine what injurious effects are to be expected from the power wave shape and to trace the cause of distortion of the wave shape.

The Golden Rule for Operators

Necessity for Kindness and Cooperation is Pointed Out in Article in The Mouth Piece

By MARGARET M. MARSHALL

"DO unto others as you would have them do unto you." Words familiar from childhood, but never more applicable to any subject than telephone work. Without that spirit we cannot do justice to each other, the company, or subscribers. With its practice, we can render service par excellence.

Let us first consider the relation of the working force with the executives. The higher the position, the greater the responsibilities that must be assumed. Every error and every instance of neglected duty will cast its reflection on the executive ability to those holding the higher positions, positions which in every instance have been attained by close attention to the smaller service which tends to make a perfect whole. There is not one position more necessary than another. It is just as essential to have efficient operators as it is to have a competent general manager; but only by co-operation can we, as an organization, attain perfection.

We will next dwell on our duty to the subscriber. Let us always remember that it's not the company or its department heads who pay salaries. It is the people who use the telephones. The money cannot come from any other source, and the Golden Rule will be found most profitable when applied to subscribers. They are entitled to the best service possible, and that service should be rendered in a cheerful and business-like manner. I grant you that all subscribers are not pleasant, but the most confirmed grouch will melt before the voice with a smile. An operator's voice travels many miles of wire in the course of a day, literally "miles and miles of smiles," which will reap a rich harvest of satisfied subscribers, and bring to the operator herself a satisfaction of work well done. Our subscribers care not whether we are dark or fair; they only ask value for their money. Beauty at any rate is not lasting; but by cultivating a cheerful disposition, we should grow sweeter as we grow older. So much for the duty of the operator to our big boss, "The General Public."

And now, last but not least, let me say a few words on a subject near my heart—the relation of operator to operator. Practice the Golden Rule in your association with the other girls; it will bring big returns in good will and affection. Help the new girl. If she is timid, be friendly; and, above all, do not be a snob. She may not be dressed so stylishly, but then there may be little brothers and sisters to be helped. She may appear quiet, and not given to smiles, but it may be her home life has some disadvantages, or, perhaps, she is among strangers and has no home at all. Open conversation in the rest rooms with your fellow-operators; get their viewpoints on different subjects. It will be helpful, even though their opinions are different from your own. I am minded of an illustration on contact and association. Two men were given a number of pennies. One of them put one in each pocket for six months, and at the end of that time found them dull and lustreless. The other man placed them all in one pocket, and at the end of six months found that contact had brightened them to the color of pure gold. So I ask you to rub elbows with your co-workers, and I am sure you will be greatly benefited. We get what we give in this life, and the following story will illustrate my point:

A man who had just moved into a small Pennsylvania town fell into conversation with an old Quaker, who was accustomed to sit on a bench in the quiet square in the center of the village.

"What kind of people live here?" asked the new-comer.

"What manner of people didst thee live amongst before?" returned the Quaker.

"Oh, they were mean, narrow, suspicious, and very unfair," answered the man.

"Then,' said the Quaker, "I am sorry, but thee will find the same manner of people here."

Not long afterward the old Quaker was accosted by another man who had come to live in the town.

"What sort of people are they here?" said the stranger.

"What manner of people didst thee live amongst before?" replied the Quaker.

A warm smile spread over the new-comer's face.

"Friend," he answered, "they were the best folks in the world. They were always friendly, kind and lovable, and I hated to leave them.

The old Quaker beamed.

"Welcome, neighbor," he said; "be of good cheer, for thee will find the same fine people here!"

SUCCESS TALKS

PROGRESS

By S. A. CHANDLER

This is a progressive age. A man who would "hold his own" must branch out; a business that would remain modern must grow.

The business man today whose establishment does not grow is only "kidding" himself when he thinks that he's RUNNING a business. There must be something wrong with his display windows, something out of gear with his service, something radically the matter with his sight, if he can't see the country growing up around him and doesn't plan ways and means of obtaining his share of the increase.

He might as well admit that he's a mossback, a has-been, a man who doesn't want to be modern. Let the dust gather on his stock and windows; let him pick up his pipe and his musty old volume and shuffle back to the rear of his shop. Let him put a jangling bell on his front door to ring him out of his dosing, well contented state of non-progression when someone DOES HAPPEN to drop in, which won't be often.

Let his business go hang! That is to say, next door, where goods are well displayed in clean, glistening showcases, presided over by wide-awake clerks who look pleasantly and humanly eager to serve.

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How the Telephone Girls Performed in France

A Story from the Butte, Montana, Post on the Work of American Girls With the A. E. F.

By CELIA GRENICKE

THE world war found American girls associated with the American army for the first time in its history in the capacity of telephone operators. This military innovation was largely in the nature of an experiment. The American army found itself confronted with the perplexing problem of securing telephone service in a country where practically none of the French operators were able to speak English.

To remedy this situation plans were gradually made for equipping the A. E. F. with American-made telephones and telephone apparatus maintained by the American boys and operated largely by American girls who were able to speak French.

The first four groups of the women's telephone unit was composed largely of college girls who spoke French, French teachers and French girls employed in this country. The fifth, sixth and seventh groups were composed almost entirely of experienced toll operators employed by the Bell telephone system.

The first appeal for volunteers was made in January, 1918. By February the first unit, composed of 33 girls, had been organized, equipped and trained in the rudiments of the telephone work, and embarked for France. The plan of organization called for a total of 500 operators to be dispatched for France in groups ranging from 30 to 60 and trained under the direct supervision of the American Telephone and Telegraph company. Pursuant to this general plan each month found a unit on its way. While Armistice Day brought joy to millions of people, sorely tried by the war, it brought tears to the eyes of the 45 operators composing the seventh unit.

Ten-forty a. m. that day found them ready to embark. Ten-forty-one on that same eventful day found them slowly turning away from the docks homeward bound. This seventh unit had received instructions to hold themselves ready for immediate embarkation and their entire equipment was already aboard the vessel that was to carry them to glory and to France.

The women's telephone unit was under the direct control of chief signal officer Brigadier General Russell. As nearly as possible the more experienced telephone operators were assigned to the positions of chief operator and supervisors. Immediately upon arrival in France each unit reported to Signal Corps headquarters at Tours. After an

extensive training of several weeks they were assigned to the different exchanges. The first group were assigned to Paris and Tours. As succeeding units arrived they were ordered to the different base ports, Le Havre, Brest, Bordeaux and Saint Nazaire. Especially trained groups were assigned to the headquarters of the First and Second Armies.

All operators of the American expeditionary forces were subject to the same discipline and regulations pertaining to enlisted men and officers. Ordinarily, a day's work was limited to eight hours, although in times of emergencies and during the great offensives the work oftentimes covered a period of from fourteen to fifteen hours. This work quickly improved the knowledge of French, as the operators dealt constantly with French operators at French exchanges and with French subscribers calling the various offices in army headquarters.

In Paris two large hotels were taken over and used for housing the ninety operators assigned to the six exchanges under the control of the signal corps. In the smaller cities, such as Neufchateau, Langres and Chaumont, where only ten or twelve operators were stationed, a residence was used. In all cases the American telephone operators were responsible for their conduct to a Y. W. C. A. hostess, appointed by the government, who lived with them in the hotel or private residence, as the case might be.

After the armistice was signed and the army of occupation moved into Germany two units of operators who were able to speak German were ordered to army headquarters at Trier and Coblenz. I was extremely fortunate in being assigned to the exchange at Coblenz, because it was here that I first came in contact with a number of Butte boys whom I had known for years.

These boys were members of the Second Field Signal battalion with the First Army. They were stationed at Grosholbeck, twenty-eight miles from Coblenz. Shortly after my arrival in Coblenz I was delighted to receive a visit from Horace Casey, popularly known as "Bones." The following day I had the pleasure of attending mess with the fourteen Butte boys who were members of the same company to which Mr. Casey belonged.

Although the use of the girls as telephone operators had been established in the beginning largely as an experiment, the result proved highly satisfactory. Even those army officers who had opposed the plan in the beginning were loudest in their praise after they had seen the efficient way in which the members of the women's telephone unit had performed their duty.

SUCCESS TALKS
VISION
By S. A. CHANDLER

The average human being never rises above the level because of one thing—he fails to use his vision, fails to seek for a different or better way to do things.

He is not original. He does what others have done before him, and contributes no new ideas of his own. He's a pattern-worker, like millions of other pattern-workers. He receives just what he is worth, for he is worth no more than the other millions like him are worth.

But the great men of the past, as well as those of today and tomorrow, are those of vision and daring—those who can and do look constantly into the future—those who are seeking daily for some new way to do things—those who are constantly finding some better, more productive way to accomplish the world's work—those who visualize the trend of the public mind and find what the public wants one year, two years, ten years hence.

Having discovered a new method, or a new product, these men of vision do not wait for some other man to say that it's practical. They have faith in the discoveries of their vision, and will back up their discoveries with their entire resources, with their good names, and with the full weight of their co-operation.

They will take a risk, yes! A risk that none of the great majority would even dream of taking. Perhaps they fail, perhaps they succeed; but, rise or fall, they back up their originality with the very best that's in them. That's why they are great men, and why the world pays them more. They're worth more to the world.

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Wireless Demonstration in Switzerland

An interesting demonstration of wireless telephony was made between Chelmsford, England, and Geneva, before a group of journalists who attended the assembly of the League of Nations at the Halle de la Reformation. At Geneva the messages were intercepted by the aerial at the recently erected Marconi receiving station, and carried over several miles of land line to the conference hall of the league. Messages were spoken by several persons, including A. Graham Bell, who used an ordinary desk telephone at Marconi House, London, which instrument was connected by a postoffice line direct to the Marconi wireless transmitting station at Chelmsford; the messages were automatically relayed to Geneva, where ordinary telephone receivers were used to listen to the messages. A "stentorphone" was also used, which consists of a magnifying trumpet from which sound is projected by means of a pneumatic fan.

"When the telephone entered the field there was no existent government monopoly to make regulations to govern its future life; no bureaucratic department had power to say how the telephone should or should not be used. The telephone was a free citizen in a free country. It is in America that the telephone art has been built up.

"When we consider that the existence in England of a state monopoly in telegraphy has resulted in reducing the value of the telephone to the British public by about 80 percent, and in depriving the country of a great industry, we realize the immense advantage which it was to the telephone in America to be born free. There was no question of a limited license, of a short period of life harassed by arbitrary regulations, and to end in uncertainty.

"The extraordinarily rapid suburban telephone service seems like magic to the visitor from England. It has been run like this for the last twenty years, and the long-distance service proper is very little less rapid between important cities. The delay between New York and Philadelphia, Boston, Washington, Chicago, rarely reaches ten minutes, and a large proportion of such calls are completed in three to five minutes. The postoffice has had a monopoly of long-distance telephony in Great Britain for twenty-five years and has not yet learned that when a telephone call is long delayed its purpose is often gone altogether. The preliminaries of a 'trunk call' in England take longer than the whole operation of a suburban call in America.

Not only is the telephone immensely more efficient in America than in Great Britain—more speedy, more accurate, more articulate, more reliable, more generally available and serviceable—but it is more economical. The actual average per telephone, notwithstanding the higher working costs, is lower in America than it is in Great Britain."

The Telephone Situation in Germany

According to Dr. Bredow of the German Postal Administration, the telegraph and telephone systems of that country are in a critical condition. There is a deficit for the current year amounting to two milliard marks, while before the war there was always a handsome surplus. With the constant rise in the price of materials and salaries it has been found impossible to make these services pay their way. Wages are six to eight times as high as formerly; the price of iron wire has risen by more than 3,000 percent, copper wire by 1,200 percent, underground cable 2,000 percent, and telephone apparatus by 2,000 to 3,000 percent. Traffic has increased heavily since the war, and repairs and extensions necessary (the latter involving 1,000,000 kilometers of wire), will entail an expenditure which cannot possibly be covered by revenue.

The government is, therefore, faced with the choice of maintaining the services on the present basis at the expense of the taxpayers and at a huge loss, or of placing them on an independent basis and raising them to their former level of efficiency. The charges for telephone service have been twice doubled since 1914, but as the cost of erection and maintenance of plant has increased about twelve and ten times respectively a great disparity has existed for several years between the benefits enjoyed by telephone users and the expenses of the administration. To bring these two into accord, a telephone tariff based on industrial and economic principles is being introduced. The flat rate will be abolished, as it is injurious both industrially and technically, giving preference to persons making constant use of the telephone at the expense of those using it less frequently. It may be recalled that in 1907, the Postal Administration projected new tariffs involving the withdrawal of the flat rate, but the introduction of these tariffs was postponed owing to the protests of larger users, and they were never put into effect.

Dr. Bredow states, according to the Berliner Tageblatt, that dissatisfaction had been caused by the proposed new regulations. The protests were, in his opinion, entirely unjustifiable. The existing tariff was unpractical and would be done away with, but the new rates would by no means correspond with the depreciated value of money and rise in prices. Referring to the forced telephone loan—a charge of 1,000 marks payable on main lines and 200 marks on extensions—he said that this was an action which called for gratitude on the part of the public, as without it the entire system must inevitably have collapsed. The sum of money thus obtained might in case of necessity prove sufficient to place the system on some sort of working basis, but further funds would be required if the urgently-needed extensions were to be carried out. Since the introduction of a higher tariff, 123,000 notices to discontinue had been received. On the other hand, 111,000 new applications had been obtained.

The new tariff was designed to place the service on a sound financial basis. It was thought that at no distant date the deficit would disappear, and, given political stability and the whole-hearted support of both officials and employes, a reduction in rates might then be possible. The re-establishment of the telephone service was in full swing and appreciable improvements had been introduced. Construction work under existing conditions, however, advanced slowly and it must be years before the German telephone system reaches its former level of efficiency.

It may be added that the number of telephone stations in Germany has increased from 1,421,000 before the war to 1,767,156 despite the loss of Alsace-Lorraine, the Polish provinces and other territory. Berlin has now 187,892 stations, Hamburg 80,697, Munich 41,504, Leipzig 37,732, Frankfort 35,003, Cologne 33,764, and altogether twenty-one towns have a total of over 10,000 stations.

Courteous Treatment

"Please" and "thank you" are more used in telephone operation than in any other service. The telephone operator handles impatient, alarmed, stupid, testy, and inconsiderate people and does so with civility and swiftness. Central does not fight or indulge in snappy stuff.

If anything goes wrong with a telephone call it is additionally provoking because the offended user has only an instrument to look at and only an invisible agency to scold. He has been taught by his experience to expect that he can turn to the telephone and through it talk to a person with more ease than he could attract that person's attention if he were with him in a room full of people.

The standard of American telephone service is so high that its very excellencies form the basis of the user's complaint when things go wrong.

The Telephone Situation Today

New Development in Raw Material, Apparatus and Supplies Brought About by Present Day Conditions

By W. N. FURTHMAN

DURING the war and after, when the law of supply and demand became an unwritten law, it came to pass that the buyer was found outside the seller's office, hat in hand, begging for raw materials and assembled apparatus. Due to the war and what has occurred since in the raw material market, it can be truthfully stated that market conditions as the buyer knew them before the war will never occur again in the telephone field.

Like any other good product, telephone equipment depends on raw materials of the highest quality, not only for its existence, but also as to its wearing efficiency, and naturally, therefore, the life of the finished product.

Manufacturers under the new order of things will be assembling telephone equipment here with raw materials that heretofore were imported from Asia and Europe. Since the buyer has been educated by war conditions and practically forced to purchase raw materials that were manufactured in America, it is going to be a difficult proposition in the future for him to refuse to purchase his supplies and equipment in this country. The buyer of telephone equipment is interested to know how these substitutions for foreign material and equipment were made, and is particularly interested to know what effect they will have on the quality of the apparatus and equipment he will be ready to purchase in the very near future. Last but not least, he wants to know the effect of such changes on basic costs and, naturally, upon prices.

Since we now see everywhere evidence that the seller will be waiting on the buyer, it will be of vital interest to all concerned to assist as much as possible in maintaining the old relations of confidence and good will. With only this object in view, the specifications and discussions as outlined in this article are submitted.

The efficiency of a condenser depends entirely upon the raw materials that are used in its production. Tinfoil is made in this country today and has been found to be second to none. There are several suppliers whose product has recently been subjected to the most rigid of tests known to the writer, and it is gratifying indeed to find that this refined mineral material has come through the substitution process in such good form.

Rice tissue paper has been made in this country since 1787, and its quality has always been considered of the highest type.

W. N. Furthman.

Paraffin is generally used in impregnated condensers, and its source and quality are well known.

Since five condensers of one microfarad each can be made from a pound of tinfoil, and a good operator can wind 100 a day, the price of this apparatus should be close to pre-war quotations. Treating and pressing condensers are both simple operations, but a condenser can be readily destroyed or its life materially shortened by excessive heat. No condenser, whatever its size or capacity, should ever be subjected in baking or treating to a temperature higher than 140 degrees Fahrenheit.

Condensers have what is known as a shelf depreciation. They are in this respect similar to dry batteries, so much so that all good manufacturers are careful to see to it that their old stock is kept as fresh as possible. Many condensers, however, have been made for a capacity of two microfarads that were only one and a half microfarads when they reached the producer. This depreciation can be materially decreased by specifying that all condensers shall be baked for three hours after treating at a temperature of 140 degrees Fahrenheit while in an upright position. Sealing condensers in a metal case is, of course, highly desirable, and the highest grade of sealing wax, free from any metal dust or coloring, should be used. Condensers absorb moisture very rapidly, and because of their use in telephone circuits, their insulation resistance should be very high. A compound consisting of 80 percent asphalt to 12 percent rosin and 8 percent motan wax is giving the best of results. In pouring the compound, care must be taken that it flows in equal amount on all sides of the condenser. By suspending the condenser unit in the case before pouring the compound this desirable result is readily obtained.

CABLE.

It has recently been determined that the standard practice of baking paper insulated cable does not thoroughly remove all of the moisture in lead covered cable. In the manufacture of paired cable the electrical tests which were made after it was completed were of such a nature as to warrant the conclusion that all of the moisture in the cable had been removed simply by the process of baking the cable for a period of 72 hours at a comparatively low temperature. When loading coils came into use in the early stages of their manufacture, they were applied only to paired cable. Upon the development, however, of a phantom loading coil, it was necessary to develop a cable which would be absolutely free of cross-talk. The development of such a cable brought about the use of a quad of wires instead of pairs, and because of the use of a phantom coil in the circuit, it was necessary for the cable to meet a very low capacity unbalance requirement. This requirement necessitated laying up of adjacent quads in such a manner as to reduce the cross-talk limits to a minimum. A very large amount of this cable was laid before it was discovered that the old method of removing moisture was not entirely successful. As an added fact it was conclusively shown by experiment that after the cable was treated in the old manner it was possible to obtain large quanti-

ties of moisture from the cable by treating it under vacuum with dry air. The dissipation losses of such a cable became so low that when phantom loading coils of 100 units of cross-talk were joined to a cable of this kind, it was possible to entirely eliminate all of the field tests which were previously employed, thus materially reducing the installation expenses of a loaded system.

The cost of treating any kind of cable by means of dry air under a vacuum is lower in expense than the old method of treating a cable, due simply to the small amount of time which is used in so treating a cable as compared to the old standard process. By sealing the ends of such a cable with paraffin, no more care is required in installing than would be used with any ordinary cable.

It has been the standard practice in the manufacture of underground cable to use colored paper in the installation of the wires in order that a satisfactory color scheme may be applied similar to the color scheme which is used in the other wool or cotton insulation cables. It has been found, however, that in the manufacture of paper insulated cables the dyes which are employed in coloring paper are of a different pigment than those which are used in the dyeing of cotton or wool, and because of this difference in the pigment, hysteresis losses are brought about which can only be traced to this cause.

An absolutely moisture-proof paper covered cable can be obtained by using a black enamel insulation on the wires before they are paper covered. The development of such a cable has until the last year been held up in manufacture, due to the difficulty which was experienced in attempting to so insulate the wires of a cable after the wires had been treated with tin for soldering purposes. It has been impossible to develop a method of applying black enamel to a tin covered wire which will not cause the tin covering of the wire to bubble through the black enamel insulation when the heat which is used in obtaining such an insulation is applied. The tinning, therefore, of a satisfactory water-proof cable can only be obtained by removing the black enamel insulation at the ends of the cable and applying the tinning operation before the soldering of the cable is made.

In the manufacture of cable for underground purposes, it has been a standard practice to specify that the sheath of the cable shall be made up of a composition of 97 percent lead and 3 percent tin. This specification has been found in the manufacture of either paired or quadded cable. Due to the high cost of tin, it has been found after several years of exhaustive tests that 99 percent lead and 1 percent of antimony is a very satisfactory substitute, and as a matter of fact it is now successfully being used in practice. This substitution of antimony for tin should result in a material decrease in the cost of manufacture and consequently therefore in price.

TELEPHONE AND SWITCHBOARD CORDS.

During the past five years considerable effort has been made to obtain a satisfactory water-proofed telephone and switchboard cord without material increase in the cost of manufacture and, therefore, in the price of such cords. The preliminary use of these cords has not been found generally satisfactory in moist climates which are found in the south and upon either of the coasts of this country, due principally to the fact that most of the manufacturers attempted to obtain a satisfactory water-proof and moisture-proof cord by impregnating the outer layers of the insulation with beeswax or other suitable material. Due to the heating up of this insulation in use by the hands of the operator, this process of obtaining a satisfactory cord was abandoned. It has recently been determined that by wrapping an insulation of cotton around the conductor of the cord and drawing such a conductor through a satisfactory asphaltum bath, before the outer insulation is applied, a cord of high permanent insulation resistance is obtained. It will be clear that a cord of this kind is free from all of the faults of the old type of water-proof and moisture-proof cords, and since this additional operation is readily applied at very small cost, the price of such a cord should be very close to the standard telephone or switchboard cord, which is not so treated.

COILS.

Physical research in the method of treating coin collector coils has disclosed that such a coil, having a solid steel core and wound with black enameled wire will develop electrical faults that are very equivalent to the flow of current in the storage battery. This condition is brought about simply by the absorption of moisture, and unless such coils are baked and treated with varnish under vacuum they cannot be wound with black enameled wire.

In treating relay induction and other coils, it has been determined that the dyes in such insulation as red rope paper bring about a destructive factor in the insulation resistance of such apparatus. This difficulty in properly impregnating coils under treatment cannot be overcome by the substitution of onion skin paper for insulation purposes around the heads of the coil and between layers of the wire.

PLATINUM SUBSTITUTES FOR KEYS AND RELAYS.

Owing to the large increase in the cost of platinum, it has been necessary to develop a satisfactory metal alloy for keys and relays. After an exhaustive physical and chemical research, it has been determined that an alloy consisting of 50 percent silver and 50 percent gold will successfully meet all of the reactive agents that are applied to platinum in endeavoring to determine the use of this metal as a standard for platinum point purposes. While it has been found that the melting point of such an alloy is lower than platinum, it is sufficiently high for all telephonic purposes. The use of this alloy in apparatus such as keys or relays should materially reduce their cost and, naturally, their price, where seven or eight contact points are used in its construction.

American Telephoning Leads the World

American telephony represents a triumph of private ownership and control with the aims of economy and efficiency, says an American correspondent of the London *Times*, as compared to the government owned British system, which has monopoly as its chief aim. He points to figure showing that 12,688,000 telephones were in use in the United States on last January 1, and adds:

"This impressive figure—nearly fifteen times the number in use in the United Kingdom at the same date—is the result of private enterprise untrammeled by bureaucratic interference or the archaic restrictions of government monopoly. It represents not alone a system of rapid communication which by its universal scope and high efficiency has become a vital element of national strength and a powerful tool of trade.

"When one sees that scale of operations of the business branch of an American telephone company," he says, "one easily realizes that the telephone is developed to a ten times greater extent here than in any European country. Nowhere else in the world but in America can the spectacle be seen of the telephone service being conducted as a modern retail business enterprise, equipped and organized to please the public and to satisfy the wants of the public quickly, efficiently and comfortably.

"BILLINGS"

A BOOB FOR BUSINESS

BY FRANK KAVANAUGH

BILLINGS came to us from some little upstate town where one turns a crank for from several seconds to a minute to secure the attention of the central girl. He had read about a central energized system, but that was all. In his old position he had been "trouble-shooter," collector, manager, traffic man and everything else, doubling occasionally when necessity demanded it, and acting as central girl himself. Usually he did this on Sunday afternoons, when the regular girl went buggy-riding with her best fellow, the son of the owner of the Boston Store.

Do not get the idea, however, that the young man was gawky or countrified. Instead, he appeared to be the embodiment of self-assurance. After the traffic man had explained that he would be placed on toll collections for a few days until he got the run of the town, Billings asked:

"How soon'll I be put to getting the new business?" The boss looked at him a moment without replying. "Anyone—even a 10-year-old kid—can go out on a motorcycle and collect a few coins."

"I want to let you get the lay of the town," the boss explained. "Do you think you could go out offhand and get new business?"

"I'm not thinking—I know what I can do," Billings replied. "I built up the Baily Crossing exchange from ten to two hundred in three years."

"You'll go collecting a few days, anyhow," the boss said, wondering just how the young upstart would fall when he was put out to get the results or go back to Baily Crossing.

For several years the opposition telephone company had slowly been encroaching on our business. For one thing they had newer equipment. Everything had been installed less than three years. They had secured some of our best operators and some of our best men. And there was no question that they were getting our business. Although we had the toll lines the state public service commission had compelled us to handle their business on our toll lines and each month saw a falling off in our receipts, while expenditures rose alarmingly. It was to get "new blood" that several young men from country towns were sent for. Billings was one of them. After he had pocketed his bill book and walked out, the boss remarked:

"That fellow will last about a week. Some gink will sell him a gold brick or the city hall or something and he'll go back to the tall uncut. We may get a good one out of a thousand."

Along towards evening Billings came in.

"Got 'm all," he announced.

"Have you turned in to Miss Stevens, the cashier," the boss asked.

"Not yet—wanted to ask a question: What's that old dead lead doing down towards the tin-plate factory. It's about dead, as far as I can see, and there's two good 50-pair cables on the poles."

"How do you know that those cables are good?" the boss, with a twinkle in his eye, asked.

"I got through collecting the chicken feed about 3 o'clock and I've been climbing each cable pole on that lead since then. I could count only four working lines on the whole lead."

"You counted right," the boss said. "That lead was built when that factory started. Instead of putting in a lot of Americans the company filled the factory with foreigners who can't speak English and there never were but four drops put into houses."

Billing nodded and went into the cashier's office. He came out as the boss was putting on his coat.

"Say, do they use telephones in China?" he asked.

"They do," the boss said.

"Do the Chinks use the same numbering system as we do?" the young man continued.

"I'm not sure," the boss said, as he walked out, "but they have some way of indicating the number of the station they want."

Billings collected for four days. At the end of that time he came into the office and turned in his cash. Then he sought the boss.

"Can I have three or four days off?" he asked.

"Rather early to be asking for a vacation," the boss remarked.

"I don't want your pay. There's a little thing I've been thinking of, and I want to see how it will come

SUCCESS TALKS

FAITH

By S. A. CHANDLER

A man losing faith closes the door on success. He loses faith because he believes that success will not be attained. Believing this, he won't put forth his best effort to attain it. He won't even see the many forerunners of success, beckoning for his attention.

A "setting" hen may be an object of humor when her misguided faith in the happy results to be gained from "setting" leads her to sit on a nest-egg for days at a time. But take away that faith and she wouldn't sit on fertile eggs. It is her faith that leads her to do the very thing which produces the desired result; likewise, it's a man's faith in his business, or in his boss, or in his ability, that causes him to do the things that produce results.

Like a steel flange, faith holds him to the tracks of progress, which not only induces him to hope for success, but also spurs him on to work for it. Having faith, and working for a definite end, he moves steadily on to the attainment of the thing he puts his faith in.

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out. I was reading a piece in a book at the public library last night about the feasibility of transmitting consonants through an echo and—"

"Take the few days off if you wish," the boss said, as he turned to his work.

For a week exactly no one saw hair or hide of Billings. Then, one morning he breezed into the office with a sheaf of contracts. Pinned to each contract was a little white piece of paper.

"Here they are, boss. I've filled that lead down to the old tin-plate factory addition and if you'll string a cable down there in addition to the ones I have filled, I'll get more contracts. Get 'em in as quick as the installation gangs can do it, will you? Or, say, if you'll give me a gang I'll drop 'em in myself."

"What the —!" The boss stopped and looked over the contracts. "These are all foreigners," he said.

"Yes," Billings said, "and everyone a home owner. You see I've got an order on the mill for the first six months' rental. I had to install two instruments and get those people interested before they would even talk. After they heard each other sling lingo a while you could not have kept 'em from signing a contract if they had to pawn their beds to pay the six months' rent."

"You'll pass," the boss said.

"And I've fixed it so a few of those foreign girls will come in and learn the boards. They can sling the lingo on that lead and at the same time they know English slang to beat the band. There isn't one of them that can't fox-trot or one-step just as good as any American ever came over the pike."

We were in need of good girls then, and the boss said nothing. As Billings was leaving he asked:

"Where have you been all the time? Out in that addition?"

"There isn't a man, woman or child out there that don't know me and all my history," Billings said. "Tomorrow night I'm to be received into the Ancient Order of Kosuskio or whatever it is—an honorary member, of course, as I'm not a Pole."

The girls proved competent after a course of training and the subscribers held. Billings seemingly forgot all about the foreign section, though, and began bringing in new subscribers from scattered portions of the city.

"How do you get them?" the boss asked him one day.

"I watch the newspapers. When I see a house for sale I watch it to see that it is sold. Then I corner the new owner, talk awhile and usually get the order."

"Um-m-m," the boss remarked.

Then came the time of the annual get-together dinner. The boss attended, of course, with his family. From the time Billings laid eyes on the young lady he never left her side. After that I think he called every evening he could get her consent. It was an open secret around the office that he was in love with the daughter of the boss.

For perseverance he was the limit. Even the boss got tired of his everlasting chasing of his daughter, and we looked for Billings to be sent back to the sticks as a result. But it was Billings himself that brought the thing to a head, and sooner than we thought.

One afternoon he breezed into the office with several contracts, laid them down. At that moment he looked toward the boss. That individual, at the same time, happened to look toward Billings.

"Hey, boss," he called. "Can I have a few days off? I want to marry."

"You impertinent ltitle scoundrel!" the boss cried, "you —"

"You remember that bunch of Polish contracts I got several months ago? Well, there's a girl down there that knocked me silly, but she's a teacher and I couldn't hold a candle to her in twirling my talker. I talked down state stuff, you know. She turned me down and I was about to let her go, when I met your daughter. Say, that young lady knows English to beat the band. I've been making her life miserable since and each night I've learned several words and how to place them. Now that teacher has consented and if you'll give me two, or say, three days off I'll—"

The old man heavied a sigh of relief. "Take as long as you like, my boy; we'll keep your salary going just the same."

"I'll brush up my talker a little and go down and get hitched," Billings said, as he went out.

"I couldn't hold a candle to her in twirling my talker."

The Maintenance of Telephone Plant

High Standard of Service and Long Life of Plant is Assured Under Proper Maintenance

By C. A. WRIGHT
Professor of Telephony,
Ohio State University.

TELEPHONE plant even if it is of the best possible construction deteriorates in service until it will not perform the functions required of it, and it is necessary to replace it. If no attempt is made to replace or repair small parts which become defective from day to day, or maintain the plant, this deterioration may be rapid, but by prompt and thorough repair or replacement of smaller portions of the plant, the time when larger sections of the telephone plant, or even the whole system, must be replaced or rebuilt may be postponed possibly for years. If such a policy is followed consistently the expense of operation will be decreased, and the telephone service given the subscribers may be maintained at a high standard.

In order that the plant may be effectively maintained, a record should be kept of the arrangement of equipment. This record should show the normal characteristics of telephone lines, as resistance and mutual capacity per mile. Such characteristics are generally essential in testing to locate faults. It should show the location of poles, cable boxes and junctions between underground and aerial cables and between cables and open wire lines. It should show what subscribers are connected to cables or open wire leads. It should show the construction of the lines, such as the kind and gauge of wire, number of cross arms, and location of wires on cross arms. The record should show where the test stations of toll lines are located. It is not so important to keep a record of this kind of the sub-station equipment and central office equipment because the various units are generally so arranged that any defect can be easily located. Circuit drawings show the details of the various units as line circuits, cord circuits, and trunk circuits.

Card files, or maps, or a combination of the two are frequently used for such records. Maps are generally most satisfactory for showing the layout of the system or large sections of the system, while card files are best suited for data about small units or sections of the plant, as poles, or "blocks."

When a telephone toll line, or trunk, or subscriber's line is cut into service after construction or changes, tests are made to determine the loop resistance, insulation resistance, mutual capacity, inductance (in cases where the circuits are loaded), and transmission equivalent.

C. A. Wright.

The loop resistance depends upon the material and gauge of the conductors and their length. The mutual capacity depends upon these factors and in addition it depends upon the location of the conductors with respect to each other and to the ground.

The insulation resistance between conductors of cables should approximate 500 megohms per mile, while each open wire conductor should have an insulation resistance of subscribers loops may vary from 100,000 ohms in wet weather to 300,000 ohms in dry weather. The inductance of a loaded circuit depends upon its length and the degree of loading. A transmission standard of 20 miles (equivalent to 20 miles of standard o. 19 gauge cable) is maintained for local circuits, and 30 miles for toll circuits.

The accompanying tables taken from the Standard and Book for Electrical Engineers present the normal constants of various types of open wire lines and cables.

For maintenance purposes telephone plant may be considered under the divisions, subscribers' stations, outside plant, and central office equipment. These divisions may be subdivided if necessary.

Faults may develop in any of this plant. In the central office, relays may become inoperative, because of bad adjustment, cords may break, switchboard lamps may burn out, jacks and plugs may wear to such an extent that they do not make contact properly, or the third wire of subscriber's lines may become crossed with other lines causing false busy tests. Jack and key springs are a prolific source of trouble. Opens develop in the switchboard cable where the skinners are soldered to the jacks. Tests for continuity with a voltmeter, or telephone receiver, and battery or with a ringing generator and bell are generally of use in locating faults in the central office. Sometimes Wheatstone Bridge or other tests are found to be useful. More useful than any tests however is a thorough knowledge of the central office circuits, and the construction and operating characteristics of the apparatus, which imply a knowledge of where and how these faults are most likely to develop.

If the telephone plant is automatic, similar faults may be expected. Springs and contacts become corroded or covered with dirt, skinners become detached from lugs and terminals, switches jam, and relays lose their adjustment. The troubles may be located and remedied in the same way as in a manual plant.

In subscriber's sets receiver cords and transmitter mouthpieces may be broken, contacts may become bent or corroded so that they do not make contact, or circuits may be opened. The grounds may become ineffective for various reasons, the dry cells of a magneto subscriber's set may be exhausted, or the line may be opened or grounded by the operation of the protectors. In most cases an inspection of a set, or simple tests, will locate the fault. The labor of actually making the repairs on subscriber's sets is generally not nearly as expensive as the time and effort consumed in visiting the subscriber's stations. This is particularly true of subscriber's stations in rural communities.

Telephone poles may decay at the ground line if they have not been properly treated, or they may be broken by accidents or storms. Insulators are frequently broken by accidents, and they offer tempting targets to small boys who take pride in their skill with stones or rifles. Guy wires and anchors rust if not properly galvanized and may be broken by vehicles. Conduit ducts may become clogged with mud or sand and man-holes frequently become filled with water.

Open wire lines are subject to crosses and grounds with other circuits. Tree grounds frequently interfere with the use of open wire telephone circuits especially in wet weather.

Drop wires may become crossed because they are not properly supported. The weight of the twisted pair may be so supported that the wires cut through the insulation.

Aerial cables may be burned by contact with power circuits, broken by rough handling, or by contant vibration or swaying,or punctured by bullets or by the boring of insects. Any such injury permits moisture to enter the cable, with the result that the insulation resistance of the circuits is greatly decreased, and that crosses or grounds may develop.

Underground cables may be injured by any of these means, and in addition may be damaged by electrolytic action, if the conduits and manholes are not kept free from water.

As in the cases of central office equipment and substation sets, a thorough knowledge of the construction and arrangement of the outside plant on the part of the maintenance force is necessary if it is to be properly maintained. They should know where it is most probable that faults will develop. Frequent inspection and prompt attention to abnormal conditions which require attention is the only effective method of keeping the outside plant in repair. It may be stated that for such inspection and repair automobiles, trucks, and trailers have been found to greatly decrease the difficulty and expense of maintaining outside plant.

Faults in subscribers' lines, trunks, and toll lines, such as those mentioned above frequently result in conditions which affect the operation of the electrical circuits. There may develop "grounds" or "crosses," which may be complete or partial (through high resistances), and permanent or intermittent, and "opens," which may be permanent or intermittent.

Crosses of the telephone lines with power circuits may introduce potentials into the circuits which may interfere with their operation, or be dangerous to life.

These faults may be located by means of tests made with a milameter, a voltmeter or a Wheatstone Bridge. To locate an open, a capacity test must be made. If the Wheatstone Bridge method is used to locate an open a pulsating or an alternating current must be applied to the Wheatstone Bridge, and a galvanometer arranged to detect the alternating current.

Routine tests to determine insulation resistance, circuit resistance, transmission and other characteristics of the circuits will frequently indicate faults before they have developed to such an extent as to cause a complaint by a subscriber. Routine tests with circuits which are duplicates of central office circuits such as cord circuits, coin-collect circuits, and ringing circuits, call attention to conditions which may exist which may prevent the operation of these circuits. In regard to these circuits it should be noted that it is the line circuits which are under test, and not the circuits which are duplicated in the wire chief's desk. Many other tests have been devised to meet special needs.

EPIGRAMS BY THEODORE N. VAIL

"Qualifications of a high-salaried man: He must have ability, judgment, courage, enthusiasm, self-confidence, energy, initiative, foresight, experience, a great knowledge of human nature and personality enough to be a real leader of men.

"He must take infinite pains in small things as well as in large. He must demand of himself as well as of others nothing but the best.

"He must have backbone and a real desire not only to excel but to serve.

"Imagination is like a very spirited horse — most valuable where the horse is useful, but it must be harnessed, saddled, and bridled. Without saddle, bridle, or harness or complete control, a splendid horse would, if you tried to use him, only destroy, not accomplish.

"Reflection: Without reflection, observation or imagination is useless, and without concentration reflection is valueless.

"Memory Cultivation: — Memory is valuable, but do not load your mind with immaterial things or things where correctness and exactness are essential and which can be easily obtained from a reference book.

"Let a young man see to it that he increases his earning power to the highest point of which he is capable, and a salary commensurate with his worth will be forthcoming sooner or later—sooner rather than later, as a rule.

"I would emphasize that it will be your own actions and the experience and knowledge gained from them, that will mold you and make for you your place as active, responsible members of society.

"Every act, small or great, will have some influence on your future; it will have its part in the formation of your character. Be careful, therefore, that each act is a rightful act, and one that will be part in the formation, for you, of a good and worthy character and reputation."

Some routine tests are made daily, while others are made weekly, monthly, or even annually, depending upon the importance and delicacy of the apparatus, or circuit. Subscribers' line circuits are tested every night in most large central offices. Continuity or ballistic tests are made to show whether or not the subscriber's receiver has been left off the hook. If the receiver has been left off the hook the voltmeter registers a steady deflection. If the receiver has not been left off the hook, the voltmeter needle deflects momentarily when the battery connected to the voltmeter and line is reversed. If the receiver has been left off the switch hook, it is not possible to ring the subscriber in the regular manner, and it may be necessary to make use of a "howler."

The cord supervisory relays are generally tested weekly by plugging into special jacks which duplicate the operting and non-operating conditions of the relays. Similar tests are made on all apparatus at necessary and convenient intervals.

In some cases when a subscribers' operator, a supervisor, or a tester finds a line in trouble or when trouble is reported on a line, it is ordered connected to a test and plugging up circuit at the trouble position which connects the line to the wire chief's desk and holds it until the wire chief, who has charge of the work of locating faults and clearing lines of them, is ready to test it. In some cases all trouble is reported to trouble clerk, who has a card file of all trouble which has been found on all of the lines. The trouble clerk sends the card of the line in question to the wire chief who orders up the line on a trunk from his desk to the switchboard or main distributing frame and tests it. When the test has been completed and the fault remedied, a record is made on the card and it is returned to the trouble clerk. The faults are removed by construction or repair gangs who in clearing lines of faults work under the direction of the wire chief.

Toll lines are maintained in the same way. Routine tests are made daily, similar to those mentioned above, with the addition of ringing, listening, and talking tests. At less frequent intervals insulation resistance, loop resistance noise and balance tests are made. If trouble is found, the faults are located and removed by the construction or repair gangs.

Effective maintenance is dependent on good material. All material should be carefully inspected when it is received. Frequently it is found desirable to make tests on wire and cable for insulation resistance, capacity, and dielectric strength. Tests for inductance, resistance, and dielectric strength are necessary many times in deciding whether or not apparatus meets specifications. Telephone transmission tests on circuits, or circuit apparatus such as transmitters, receivers, repeating and induction coils, and condensers should be made in many cases.

Table of Constants and Transmission Equivalents of Non-Loaded Metallic Open Wire Circuits.

Gage No.	TYPE OF CIRCUIT: Bare or Insulated	Physical pairs or phantoms	Constants of Circuit per Mile of Loop (two wires): Effective resistance (ohms)	Effective resistance (henries)	Effective capacitance (mf.)	Transmission Equivalent: Miles equivalent to one mile of No. 19 A.W.G. standard cable	Reciprocal	Miles equivalent to 30 miles of No. 19 A.W.G. standard cable
8 B.W.G.	Bare copper	Pairs	4.08	0.00337	0.00898	28.6	0.035	860
8 B.W.G.	Bare copper	Phantoms	2.04	.....	.....	34.5	0.029	1035
9 A.W.G.	Bare copper	Pairs	8.78	0.00359	0.00838	15.6	0.064	470
9 A.W.G.	Bare copper	Phantoms	4.39	.....	.....	18.5	0.054	755
12 S.W.G.	Bare copper	Pairs	10.26	0.00366	0.00822	12.7	0.079	380
12 S.W.G.	Bare copper	Phantoms	5.13	.....	.....	15.0	0.067	450
14 S.W.G.	Bare copper	Pairs	17.4	.....	.....	8.2	0.122	246
14 S.W.G.	Bare copper	Phantoms	8.70	.....	.....	9.5	0.105	285
9 A.W.G.	Bare copper clad (47 percent)	Pairs	18.9	0.00390	0.00838	8.1	0.123	243
10 A.W.G.	Bare copper clad (47 percent)	Pairs	23.5	0.00394	0.00820	6.8	0.147	204
12 A.W.G.	Bare copper clad (47 percent)	Pairs	37.2	0.00408	0.00786	4.9	0.204	147
14 A.W.G.	Bare copper clad (47 percent)	Pairs	59.4	0.00420	0.00755	3.6	0.28	108
8 B.W.G.	Bare iron (BB)	Pairs	....	.....	.....	4.5	0.22	135
10 B.W.G.	Bare iron (BB)	Pairs	....	.....	.....	4.0	0.25	120
12 B.W.G.	Bare iron (BB)	Pairs	85.0	0.01500	.....	3.1	0.32	93
14 B.W.G.	Bare iron (BB)	Pairs	....	.....	.....	2.5	0.40	75
14 A.W.G.	Copper (rubber and braid)	Pairs	27.1	.....	.....	1.2	0.8	36
18 A.W.G.	Copper (rubber)	Pairs	68.3	.....	.....	0.9	1.1	27
17 A.W.G.	Copper-clad (drop)	Pairs	....	.....	.....	0.6	1.7	18

Table of Constants and Transmission Equivalents of Non-Loaded Metallic Cable Circuits.

Gage No. A.W.G.	TYPE OF CIRCUIT: Construction	Physical pairs or phantoms	Constants of Circuit per Mile of Loop (two wires): Resistance (ohms)	Capacity (mf.)	Insulation (megohms)	Transmission Equivalent: Miles equivalent to one mile of No. 19 A.W.G. standard cable	Reciprocal	Miles equivalent to 30 miles of No. 19 A.W.G. standard cable
19	Dry-core paper cable	Pairs	88	0.060	500	1.00	1.00	30
22	Dry-core paper cable	Pairs	176	0.83	500	0.60	1.66	18
22	Dry-core paper cable	Phantoms	88	.....	...	0.68	1.48	20
22	Dry-core paper cable	Pairs	176	0.070	500	0.65	1.53	20
22	Dry-core paper cable	Phantoms	88	.....	...	0.74	1.36	22
19	Dry-core paper cable	Pairs	88	0.074	500	0.90	1.11	27
19	Dry-core paper cable	Phantoms	44	.....	...	1.01	0.99	30
16	Dry-core paper cable	Pairs	44	0.074	500	1.28	0.78	38
16	Dry-core paper cable	Phantoms	22	.....	...	1.43	0.70	43
14	Dry-core paper cable	Pairs	27	0.074	500	1.61	0.62	48
14	Dry-core paper cable	Phantoms	13	.....	...	1.82	0.55	55
13	Dry-core paper cable	Pairs	22	0.074	500	1.82	0.55	55
13	Dry-core paper cable	Phantoms	11	.....	...	2.04	0.49	61
10	Dry-core paper cable	Pairs	11	0.074	500	2.55	0.39	77
10	Dry-core paper cable	Phantoms	5.5	.....	...	2.85	0.35	86
19	Submarine (impregnated paper)	Pairs	88	.....	500	0.53	1.9	16
3 No. 22	Submarine (rubber)	Pairs	59	.....	...	0.63	1.6	19
16	Submarine (impregnated paper)	Pairs	44	.....	500	0.71	1.4	21
22	Switchboard cable (cotton and silk)	Pairs	176	.....	100	0.45	2.2	14
19	Switchboard cable (cotton and silk)	Pairs	88	.....	100	0.59	1.7	18
19	Switchboard cable (wool)	Pairs	88	.....	100	0.67	1.5	20
16	Switchboard cable (wool)	Pairs	44	.....	100	0.91	1.1	27

Modern Development in Telephone Transmission

A Paper Presented Before the South African Institute of Electrical Engineers, September, 1920

By J. W. KEEFE

IN this paper I propose to describe briefly the developments in the art of transmitting speech electrically by means of wires or cables, which have resulted partly from a theory of the phenomena met with in the attempts to convey speech over great distances, and partly from the application of the results of experiments on the discharge of electricity through gases, and the theory deduced therefrom.

The first development referred to is associated for all time with the name of Pupin, who first put into practical shape the theory of telephonic transmission, which had been evolved more or less vaguely by previous investigators. The second is due to the historic work of Sir J. J. Thomson, followed up by Fleming in England and Lee de Forest in America, resulting in the practical application of the thermionic valve to wireless telegraphy and telephony and the development of the vacuum tube telephonic repeater.

I do not propose to deal with either radio telegraphy or telephony, as these branches of electrical activity would each demand a paper, or rather several papers to itself.

In describing the developments outlined above, I shall have to deal fairly fully with the elementary theory of transmission, leading to the development of the loading of telephone circuits, and in doing this I shall necessarily traverse ground which is already familiar to telephone engineers. I hope, however, by keeping in view as much as possible the physical aspect of the problems involved, and relegating to the list of references such mathematical analysis as is not absolutely necessary to the argument, I may be able to present the subject in an interesting way, both to experienced telephone engineers and to those who have not hitherto made any close study of it. From this I propose to pass on to the application of the thermionic valve or vacuum tube to telephone work, giving a brief account of the development to date in this direction, particularly in the United States.

The telephonic transmission of speech over long distance lines offers special difficulties on account of the minute quantity of energy involved, the high frequency of the electric waves propagated, and the necessity of preserving the quality or "timbre" unaltered.

In telephonic transmission, currents of different frequencies are involved, the oscillations in insulated conductors having a frequency of the order of several hundreds per second, with a variable velocity of the order of 1,000 miles per second and a variable wave length of from one to one hundred miles. The various harmonics which go to make up the distinguishing quality of the voice change in their relative intensity in the process of transmission, with the result that the speech received over a line on which the transmission is poor, is altered and distorted so as to be unintelligible.

The problem is, therefore, twofold—it is necessary not only to transmit from the generating to the receiving apparatus the greatest possible quantity of energy, but also to attain such conditions that the voice reaches the receiving end with all its component harmonics attenuated to the same degree.

GENERAL THEORY OF TELEPHONE TRANSMISSION.

The first attempt to enunciate a working rule, based on theory, for the guidance of telephone engineers in the design of long distance lines was made by Sir William Preece, in an endeavor to apply the formula given by Lord Kelvin in his investigations of the conditions governing the speed of transmission of telegraph signals in submarine cables. Kelvin's formula for the time constant of a telegraph circuit is:

$$A = B\,k\,r\,l^2$$

where B is a constant depending principally on the units used, k and r the capacity and resistance per unit length, and l the total length. From this, Preece (in a discussion on Professor S. P. Thompson's paper on "Telephonic Investigations") in 1887 enunciated the rule (since known as the "K. R. Law") as follows: "We take the total capacity of the circuit (K), which is found by multiplying the length of line by its capacity per unit length and the total resistance (R), which is found by multiplying the length of line by its resistance per unit; and the result is that we get a law determining the distance to which we can speak, that is simply expressed by the product K by R" (1). This statement may be extended as follows: (2) Limiting distance (S) of speech = Kr × constant A or using the unit notation $S = A\,k\,r\,l^2$ from which $l^2 = A/Kr$, and $l = \sqrt{A/Kr}$. By substituting values for A obtained by experiment, Preece arrived at a series of values for the limiting distance of speech on circuits of different kinds of wire and cable (3).

This rule aroused a good deal of criticism, that of Heaviside in particular being very severe. It must be admitted, however, that it formed a guide in the design of successful long distance telephone lines for a number of years, and it will be shown later on in this paper that under certain conditions it agrees with the conclusions of the more comphensive modern theory. At this time (1887) it is evident that a number of electrical engineers had come to the conclusion that electrostatic capacity was the chief obstacle to the extension of the distance over which speech could be transmitted in cables. (4) Heaviside had in 1887 worked out his conception of the "distortionless circuit," a conception which really pointed the way to the solution of the problem of commercial long distance transmission. Unfortunately, his results were expressed in cumbrous formulæ, arrived at by the use of mathematical processes which few but the highly trained mathematician could follow, and it was not until thirteen years after that the problem was attacked in such a way that the results could be put into practical use.

It is difficult to estimate the enormous developments that might have resulted had Heaviside been more approachable by those he termed "practicians" (5).

He did, however, in one of the passages referred to in the footnote (2), state definitely, "Increasing the inductance is another way of improving things." Subsequently several attempts were made to arrive at a method of improving transmission in cables, notably by S. P. Thompson, who suggested

(1) Journal of the Society of Telegraph Engineers, XVI, 84 (J. E. Kingsbury, "The Telephone and Telephone Exchanges," 1915, p. 280).

(2) "The Telephone," Preece and Maier, 1891, pp. 124-126.

(3) See also "A Manual on Telephony," Preece and Stubbs, 1893, chap. xxxi.

(4) J. E. Kingsbury, op. cit. pp. 280-282.

(5) O. Heaviside, "Electrical Papers," II, 19, and "Electromagnetic Theory," I, 141 (see J. E. Kingsbury, op. cit., pp. 434-436, for characteristic passages and comments).

the provision of inductive leaks or shunts, at regular distances throughout the length of a submarine cable. Patents embodying these suggestions were taken out in 1891 and 1893, but no cable constructed in the ways described was, so far as I am aware, ever made use of (6). It is pointed out by Dr. J. A. Fleming that at this time the idea that the effects of distributed capacity could be annulled by inductance had arisen in other minds than Heaviside's, and his mathematical investigation of the theory of the Thompson cable demonstrates that "the rule for spacing the shunts . . . is verbally the same as that for spacing the inductance coils in a Pupin cable" (7).

Heaviside's mathematical researches showed that telephone transmission consisted in the propagation along conductors of finite length of electrical waves, and that the obstacles in the way were not capacity, or resistance, or inductance alone, as had been supposed at one time or another, but that four electrical constants had to be taken into account, namely, the three mentioned, and, in addition, the leakage. Also, that the problem was further complicated by the fact that sound waves, and consequently the resulting electrical waves, were not simple periodic functions. From the fact that the electrical transmission of speech is essentially a conversion of sound waves into electrical waves at either end of a line, their propagation along it, and their reconversion into sound waves at the other end, it is evident that the waves as emitted at the sending end must, if articulate and audible sounds are to be produced at the receiving end, undergo as little alteration as possible (both in amplitude and form) in their passage; that is, the attenuation (or diminution in amplitude), and the alteration of form (or distortion) of all waves within the range of frequency of audible sounds, should be reduced to the minimum possible. Pure attenuation or decrease in amplitude within limits is not of great importance, provided distortion is kept down, as the ear is sensible to waves of minute amplitude. As a speech wave consists of a number of simple periodic components of different frequencies and amplitudes, having differing wave lengths and traveling at different speeds, and these are affected in different degrees according to their frequency, the form of the received wave may be so altered as to be unrecognizable.

(6) S. P. Thompson, British patents No. 22304, 1891, No. 13064 and 15217, 1893. Electrical Congress, Chicago, 1893. Paper on "Ocean Telephony."

(7) J. A. Fleming, "The Propagation of Electric Currents in Telephone and Telegraph Conductors," 1911, pp. 106, 133.

The attenuation of a simple periodic wave of current traveling along a conductor is dependent upon a quantity "A" called the *attenuation constant*, the derivation of which will be given later. This quantity is a function of the line constants: Resistance (R), Capacity (K), Inductance (L), Leakance (S), and the frequency. Leakance, being the conductance of the dielectric surrounding the conductor, is expressed as the reciprocal of the insulation resistance. The amplitude of the transmitted current is reproduced logarithmically in the ratio $1 : e^{-a}$ per unit length of line. The speed of transmission W is equal to $n\lambda$ where λ is the wave length and n the frequency. It can also be expressed as $W = P\beta$, where $p = 2\pi n$ and β is a function of R, K, L, S, and p, called the wave length constant. Consequently, waves of different frequencies or wave lengths are transmitted at different speeds, and are attenuated at different rates.

Heaviside showed that if the electrical constants mentioned above were so proportioned that $KR = LS$, simple periodic waves of all frequencies would travel at the same speed and be equally attenuated, and that the wave form of a complex wave (consisting of a number of simple periodic components) would not be distorted. Hence the terms "distortionless circuit' and distortionless cable," signifying that the forms of electric waves transmitted over such a circuit or cable would be altered, although reduced in size or amplitude. Distortion may therefore be reduced in a number of ways, each having for its primary object the attainment of the condition $KR = LS$. These are, for cables, where in general the product LS is very small compared with KR.

(1) Reducing the capacity K.
(2) Increasing the inductance L.
(3) Reducing the resistance R.
(4) Increase the leakance S.
(5) Changing the constants so that LS is equal or nearly equal to KR.

Any or all of these changes are possible, but for reasons principally of practicability and cost, attention was directed chiefly to the reduction of capacity, a great advance being made in this direction by the invention of the dry core cable, described by W. R. Patterson at the 1889 Cable Conference of American telephone and telegraph engineers (8). Attempts to solve the problem by increasing the inductance were, as mentioned above, suggested by Thompson and others. In considering the method of improving transmission by the addition of inductance, the difficulty arises that K, R, and S are uniformly distributed along the length of a properly constructed cable, whereas, apart from the method, due to the Danish engineer, C. E. Krarup, of wrapping each conductor with fine iron wire throughout its length, the only way of increasing L would be to insert inductance coils in the line, resulting in a non-uniform distribution. To Pupin is due the credit of showing, both mathematically and experimentally, how such lump inductances could be spaced so that the resultant effect should be as nearly as possible the same as that of uniformly distributed inductance.

In explaining this theory of a non-uniform conductor, with inductance coils at regular intervals, Pupin made use of the mechanical analogy of a weighted or loaded string. Hence the terms "loading" and "loading coils." Briefly expressed, Pupin's theory, as described in the British patent (No. 12733 of 1900), is that by the addition of inductances or "reactance sources" distributed along a conductor, the amount of current necessary for the transmission of a given amount of electrical energy by electrical waves is reduced, the attenuation is reduced, and the efficiency of transmission increased. Also, he showed how the inductances could be spaced so that "the resulting wave conductor is equivalent, within proper limits, to its corresponding unifor mconductor, but increased effective inductance.' (9)

The rule for the spacing of inductances, as enunciated by Pupin, is that a non-uniform line (*i.e.*, one with loading coils inserted at intervals) will be electrically equivalent for transmission purposes to a uniform line having the same total resistanceand inductance, if half the distance between two adjacent coils, expressed as a fraction of 2π taken as the wave length, is an angle so small that its sine has practically the same numerical value as that angle in circular measure. For instance, if there are ten coils per wave, the angular distance γ between two successive coils is $2\pi/10 = 36° = 0.628318$ . . . and $\frac{1}{2}\gamma = \pi/10 = 0.314159 = 18°$. But the sine of $18° = 0.3090$, and therefore $\frac{1}{2}\gamma$ exceeds sin $\frac{1}{2}\gamma$ by 1.6 percent only. It can be seen that if the number of coils per wave length is reduced, and consequently the distance between adjacent coils increased, the difference between $\frac{1}{2}\gamma$ and sin $\frac{1}{2}\gamma$ increases; for example, with four coils per wave length the difference is 11 percent. Hence, if there are at least nine coils per wave, the non-uniform cable is for that frequency practically equivalent to a cable in which

(8) See "The Telephone and Telegraph Exchanges," J. E. Kingsbury, 1915, p. 288.

(9) British Specifications, No. 12733 of 1900.

the same inductance and resistance is smoothly distributed. Such a cable, if not distortionless, would be at least much less distortional than an ordinary unloaded cable (10).

TRANSMISSION EQUATIONS.

As indicated in a previous passage, the attenuation constant α is a measure of the transmission efficiency of the line, since at any distance from the sending end

$$C_x = C\alpha\epsilon^{-\alpha x} \qquad (1)$$

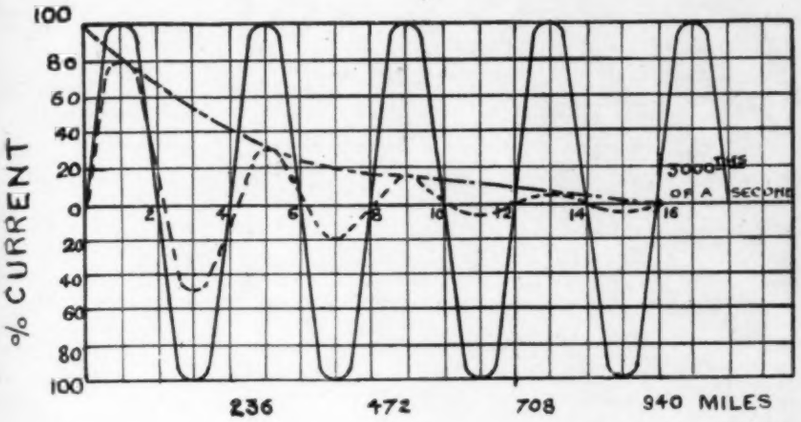


Fig. 1.

$C\alpha$ is the current at the beginning of the line.

ϵ is the base of natural logarithms = 2.71828.

α is the attenuation constant or attenuation per unit length.

The expression for the attenuation constant α is*

$$\alpha = \sqrt{\tfrac{1}{2}\,pK \times (\sqrt{p^2L^2 + R^2} - pL)} \qquad (2)$$

where

L = Inductance in henries per unit length
K = Capacity in farads per unit length
R = Resistance per unit length
P = Frequency = $2\pi n$

In this equation n is the average telephonic frequency, usually taken as 750 or 800 p.p.s. In general, calculations p may be taken as 5,000. With cables of small gauge conductors, the inductance L is so small as to be negligible, and the formula for the attenuation constant becomes

$$\alpha = \sqrt{\tfrac{1}{2}\,pKR} \qquad (3)$$

Hence, if we have two cables having different capacities and resistances, K_1 and K_2, R_1 and R_2, and negligible inductance, their attenuation constants A_1 and A_2 will be proportional to K_1R_1 and K_2R_2. On the experimental verification of this relation, Preece's "KR Law" was founded.

LEAKANCE.

The formula given above take no account of leakage. If the leakance, expressed in ohms per unit length, be called S, then equation (2) for the attenuation constant becomes

$$\alpha = \sqrt{\tfrac{1}{2}\sqrt{(R^2+p^2L^2)(S^2+p^2K^2)} + \tfrac{1}{2}(RS - p^2LK)} \qquad (4)$$

WAVE LENGTH CONSTANT.

Fig. 1 shows curves for a simple sine wave current having a wave length of 236 miles, and a frequency of 750 p.p.s. propagated over a length of 940 miles of 400 pounds copper conductor. The broken periodic curve shows the corresponding attenuated wave, and the curve joining the maxima values or the crests of the latter gives the value of the attenuated curves at any point calculated from the equation $y = 100\epsilon^{-\alpha l}$ which is the equivalent to scale of the formula (1). The instantaneous value is $y = 100\epsilon^{-\alpha l}\sin\beta l$. The quantity β is called the wave length constant. In the figure a complete period of length 236 miles would represent one complete revolution of a rotating vector, having amplitude A = 100. Consequently β represents the change in the angle per unit length of line. In this case, since the wave length is expressed in miles, the angle β equals $2\pi/236$ that is .0266 radian. The relation between length and time in the equation dealing with sine functions may be shown thus: Take any point on the common time and length axis, for example, where t = 16 and l = 940m., then (a) $y = \text{Sin } 2\pi \times 750 \times \frac{16}{3000} = \text{Sin } (2\pi \times 4) = \text{Sin } 25.1$, and (b) $y = \sin\beta l = \sin(.0266 \times 940) = \sin 25$, which is practically the same value as in case (a) (12).

The value of the wave length constant expressed in the terms of the physical constants of the line is

$$\beta = \sqrt{\tfrac{1}{2}\sqrt{(R^2+p^2L^2)(S^2+p^2K^2)} - \tfrac{1}{2}(RS - p^2KL)} \qquad (5)$$

DISTORTIONLESS CIRCUIT.

If, as is usually the case in cables, PK is great in comparison with S, and pL be made large in comparison with R, all quantities involving the frequency factor can be eliminated, and

$$\text{Attenuation constant } \alpha = \frac{R}{2}\sqrt{\frac{K}{L}} + \frac{S}{2}\sqrt{\frac{L}{K}}$$

If S be negligible, then this reduces to

$$\alpha = \frac{R}{2}\sqrt{\frac{K}{L}}$$

$$\text{also } \alpha = \sqrt{SR}$$

$$\text{and } \beta = p\sqrt{KL}$$

These equations show that the circuit is distortionless, which means that current waves of all frequencies will travel at the same speed, that is, $1/\sqrt{KL}$, and are all attenuated at the same rate, namely, $\epsilon^{-\sqrt{SR}}$ per unit length.

COMMERCIAL LOADING OF TELEPHONE LINES

Shortly after the publication of Pupin's invention, it was taken up vigorously by the American Telephone & Telegraph Company in America, by the British postoffice and the National Telephone Co. in England, and by the German administration. Much experimental work had to be done, however, before loading was adopted commercially on an extensive scale. Apparently the first loaded cable of any length to be used commercially was a 10-mile length between New York and Newark, New Jersey, referred to by Mr. Gherardi in the discussion on H. V. Hayes' paper read at the International Electrical Congress, St. Louis, 1904. The first work in America was the application of loading to open wire and standard cable circuits, attention being devoted later to per mile). Two loaded circuits were the loading of phantom circuits and high grade trunk lines of No. 8 B. & S. gauge wire, and the design of special

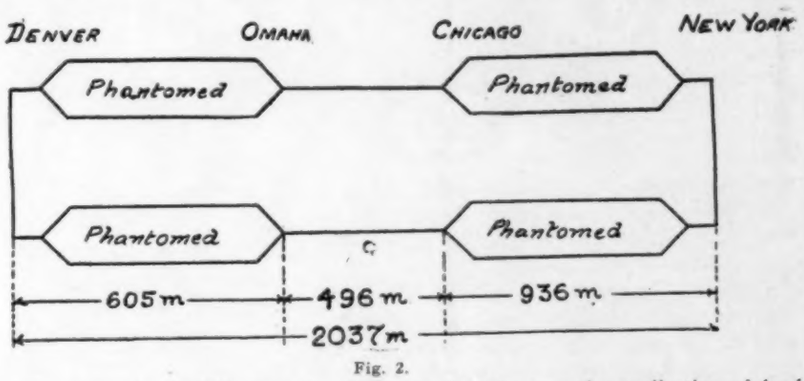


Fig. 2.

(10) Dr. Fleming, "Propagation of Electric Currents, etc.," p. 123.

*See for derivation of this and other expressions, Appendix I. to this paper.

(12) J. G. Hill, "Telephonic Transmission," p. 20.

cables for phantom working. In 1911, telephone communication was established between New York and Denver, a little over 2,000 miles, the line being of No. 8 A. W. G. copper (435 pounds provided, these being phantomed for part of the distance and the phantom circuits loaded. Arrangements were afterwards made to provide phantom circuits throughout the total distance.

The New York to Denver circuit, using phantoms where existing, and including the reflection loss, due to the irregularity of the arrangement, was equivalent to about 30 miles of standard cable. When connected through on the unphantomed physical lines it was equivalent to about 32 miles of standard cable. It was estimated when the final phantom scheme was completed, the New York-Denver phantom connection would be equivalent to 28-29 miles of standard cable, as against 69 miles for the non-loaded No. 8 circuit. (B. Gherardi, New York Telephone Society paper, 1911.) The general arrangement is shown diagrammatically in Fig. 2.

Considerable trouble was experienced with the early loaded aerial circuits in America, as it was found that the glass insulators hitherto used were not of sufficiently high insulation, and that, as might be expected, the effect of leakage on a loaded circuit had much more effect in lowering the transmission efficiency than on a non-loaded line. Glass insulators have, therefore, been replaced on long loaded lines by the double-shed porcelain type. The effect of leakage on loaded aerial lines as compared with unloaded lines is shown in Fig. 3.

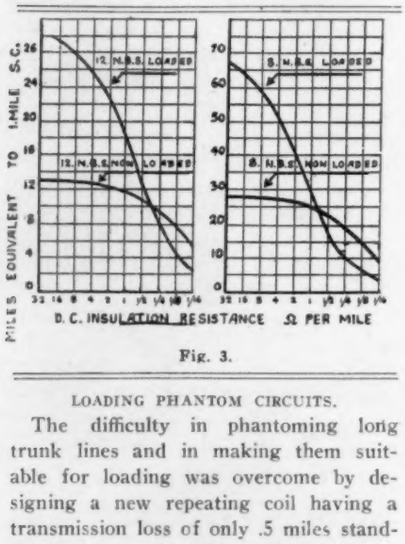

MILES EQUIVALENT TO 1 MILE S.C.
12. N.B.S. LOADED
12. N.B.S. NON LOADED
8. N.B.S. LOADED
8. N.B.S. NON LOADED
D. C. INSULATION RESISTANCE Ω PER MILE

Fig. 3.

LOADING PHANTOM CIRCUITS.

The difficulty in phantoming long trunk lines and in making them suitable for loading was overcome by designing a new repeating coil having a transmission loss of only .5 miles standard cable as against 3 miles for the ordinary type, and a loading coal differently wound from that used on physical circuits. The ordinary loading coil was found to unbalance the phantom circuit and increase its effective resistance so as to make it both noisy and inefficient. A typical unloaded phantom circuit is shown diagrammatically in Fig. 4. Evidently, if the side circuits are not perfectly balanced, the phantom circuit will be noisy. If a circuit with ordinary loading coils is phantomed, the current for the phantom circuit flows through

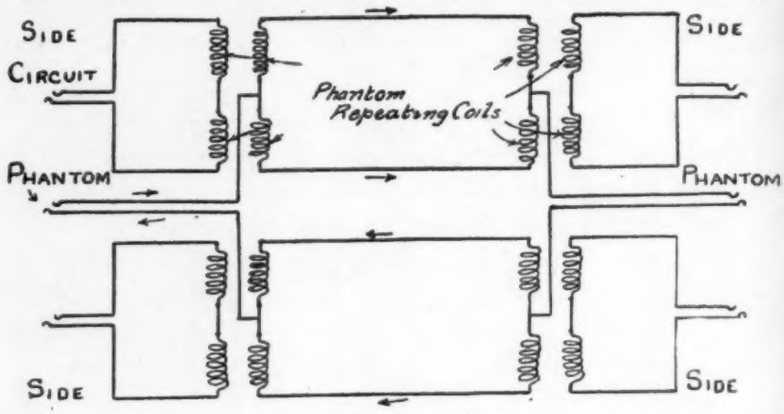


Fig. 4.

the two sides of each side circuit in parallel, magnetizing the two halves of the loading coil in opposite directions, resulting in the production of consequent poles and considerable magnetic leakage (Fig. 5b). This leakage being different for different coils, it was practically impossible to make the two side circuits sufficiently alike for balance. The magnetic leakage might also affect adjacent coils, causing cross-talk and loss of efficiency. Loading coils for phantomed circuits are therefore wound as shown in Fig. 5. The coils have to be carefully adjusted for electrostatic balance as well as electromagnetically. With these coils, satisfactory phantom circuits can be derived from loaded physical circuits in the usual manner. The phantom itself, however, cannot be loaded.

PHANTOM LOADING COIL.

Although the coil just described is so wound that whether the current flowing in the side circuit is that for the physical or phantom operation, no adverse effect is produced, the currents for the phantom circuit flow in parallel over the windings of the loading coil and produce no resultant magnetic flux. Hence, to load the phantom itself, a differently wound coil (Fig. 6) is used, which is arranged so that the magnetizing effect produced by the currents in the phantom circuit are all in the same direction, as in an ordinary loading coil, and the maximum inductance is obtained. Currents flowing in the physical circuit, however, neutralize each other and have no resulting magnetizing effect on the core.

DUPLEX OR MULTIPLE TWIN CABLES.

"Multiple Twin," "Quadded," or "Duplex" cables may fitly be considered here, as their development is largely the result of the application of loading to phantom circuits. It was found that if cables ordinarily quite efficient were used for loaded phantom circuits, the difference in electrostatic capacity of different pairs was enough to cause serious overhearing ("cross-talk") between circuits. To reduce this effect as much as possible, the duplex cable was introduced, and a number of loaded and phantomed cables have been made on the principle, of which the following details of tests, etc., of some important trunk cables in England and America may be of interest:

Boston-Washington Loaded Underground Cable (475 *miles*)

This cable consisted of

	Pairs
No. 10 B.&S. conductors (166 lbs)..	14
No. 13 B.&S. conductors (83 lbs.)..	42
No. 16 B.&S. conductors (42 lbs.)..	18

The No. 10 B. & S. conductors form the center core, which is surrounded by 36 pairs of No. 13 B. & S. conductors, the 18 pairs of No. 16 conductors being placed at the outside of the cable to fill the interstices between the No. 13 conductors. The remaining six pairs of No. 13 gauge occupy the interstices between the inner core of the No. 10 conductors and the outer layer of No. 13 conductors. All the Nos. 10 and 13 conductors are laid up in quad formation, except the odd six pairs of No. 10 mentioned above. The center quadruplet is formed of one pair having a lay of 6 inches, the other pair having a lay of 7 inches, and the two are then twisted together with a lay of 12½ inches. Throughout the cable it is arranged that as nearly as possible any two adjacent pairs shall have different lengths of twist. It is of the greatest importance that the conductors be well balanced electrostatically; that is, that the capacity of each wire

London-Liverpool Loaded Underground Cable (90 miles)

Weight of Conductor per Mile (pounds)	Direct Current Tests				A.C. Tests ($2\pi f = 5000$)
	Resistance Ohms per Mile Loop	Inductance Henrys per Mile Loop	Insulation megohms per Mile Loop	Capacity Mf. per Mile Loop	Attenuation Const. per Mile Loop
300.....	6.28	0.058	6.750	0 0545	0.00413
200.....	9.19	0 054	17,610	0 0572	0.00618
150..... ..	12.44	0.052	27,600	0.0685	0.00846
150 Phantom..	6.22	0.033	.....	0.1008	0.00682
*100.....	17.32	0.053	39,600	0.0575	0.01014
100 Side	17.90	0.053	32,670	0.0579	0.01057
100 Phantom..	8.95	0.034	.....	0.0864	0.08370
300.....	Not yet loaded	Not yet loaded	Not yet loaded	0.0857	.....
200.....	do.	do.	do.	0.0853	.....

* Not phantomed.

London-Birmingham Loaded Underground Cables (109.5 miles)

300.....	6.55	0 055	21,800	0.0568	0.00408
200.....	9.62	0 054	19,000	0.0655	0.00664
150.....	13.13	0 054	17,890	0.0697	0.00884
150 Phantom..	6.56	0.035	.....	0.1057	0.00756
*100.....	18.38	0.053	20,600	0.0568	0.01074
100 Side	18.95	0.054	.....	0 0575	0.01092
100 Phantom..	9.50	0.036	.....	0.0905	0 00926
200.....	Not yet loaded	Not yet loaded	Not yet loaded	0.0823	.....
300.....	do.	do.	do.	0.0844	.....

* Not phantomed.

to the other pair of the quad should be exactly the same as that of its mate. This requires great care in manufacture to make certain that the conductors are laid up symmetrically, and that the two pairs of each quad are twisted symmetrically. This has proved a very difficult problem, as a slight difference in the hardness of the wires or in tension will result in one remaining straight while the other twists round it. Besides the care used in manufacture of these cables, it is found necessary when jointing the cable after laying, to make tests at intervals of the capacity unbalance in each direction, and to join them together in such a way that the unbalances neutralize each other. The reason for these elaborate precautions is that with high efficiency loaded and phantomed cables an amount of cross-talk which would not be noticeable in ordinary work would be objectionable. The New York-Washington cable was designed to be loaded at intervals of 1.4 miles, bringing the equivalent of the No. 10 phantom circuits to 13 miles standard; that of the physical No. 10's between New York and Washington being 16 miles standard, and the phantomed No. 13's, 28½ miles. The phantomed No. 10's between Boston and Washington would have an efficiency of 26 miles of standard cable, this through route being used in emergencies only.†

† The information on the Birmingham and Manchester—London cable is obtained from Mr. J. G. Hill's article, "The Loading of Underground Telephone Cables, &c.," Post Office Electrical Engineers' Journal; that on loading phantom circuits and the construction of the Boston-Washington cable from a paper read by Mr. B. Gherardi before the New York Telephone Society in 1911.

For information regarding balancing of cables, see article by Mr. S. A. Pollock, Post Office Electrical Engineers' Journal, April, 1914, and January, 1915.

SPACING OF LOADING COILS.

When loading was first introduced, opinions were somewhat at variance as to the most efficient spacing of loading *average* frequency of speech currents. As the fundamental frequency of the human voice has a range from about 80 (the lowest male voice frequency) to coils, consistent with economy. These differences appear to have been due to a great extent to the values taken by different experimenters as representing the about 800 (the highest female voice frequency), and these are usually combined with a number of overtones, the determination of the value of the mean frequency to be used in telephone transmission calculations was a rather difficult one. It was decided at the International Congress of Telephone and Telegraph Engineers at Paris in 1911 that for practical calculations this frequency should be taken as approximately 800 p.p.s., so that the product $2\pi \times$ frequency should be 5,000.

Mr. Gherardi in his paper on the commercial loading of telephone circuits, read in 1911, gives the following details of spacing that had been found to give good results in America:

Light, .05 henry per mile, spacing 2½ m.
Medium, .1 henry per mile, spacing 1¾ m.
Heavy, .2 henry per mile, spacing 1¼ m.

In general, loading as used in England is lighter than used in America and Germany, with practically equivalent results. It has been suggested that differences of language and intonation may have some effect. Also, although the resultant decrease in attenuation on a loaded line can be determined by test and calculation, the practical effect is usually stated in terms of the equivalent length of standard cable obtained from speaking tests, which are necessarily affected by the judgment of the individual making them, the acuteness of his hearing, etc. Some engineers have proceeded on the rule that the product of the attenuation constant by the length of line should not exceed a certain constant for the limit of commercial speech, but the figures chosen differ slightly. The spacing of coils is sometimes expressed as so many "loads per second," that is, as the number of coils passed through by a wave per second. This number as given by different experimenters ranges from 6,325 for the light loading used by the postoffice in England to 8,000 in Germany. As an example of the use of this constant, assume that a 20-pound cable capacity is loaded with .25 henry per mile. The wave length at a frequency of 800 p.p.s. would be 10.8 miles, the wave velocity 8,620 miles per second; hence, if the figure for "loads per second" be 7,000, the coil spacing is $8{,}620/7{,}000 = 1.23$ miles, or, roughly, 9 coils per wave length.

STANDARD CABLE AND STANDARD OF TRANSMISSION.

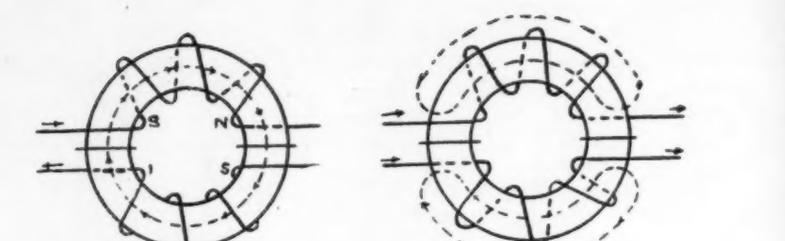
For practical tests to determine the relative efficiency of any cable or open wire circuit, so far as the line itself is concerned, or the relative efficiency of any combination of lines, cable, and associated apparatus, a standard of com-

parison was necessary. For this purpose a standard cable and a standard of transmission were decided upon, those used by the British postoffice being practically identical with the standards originally adopted by the American Telephone & Telegraph Company. The cable taken as standard is a dry core paper insulated cable having the following constants per loop mile: Conductor resistance, 88 ohms; mutual capacity, .054 mf.; inductance, 1 millihenry; leakance, 5 micromhos.

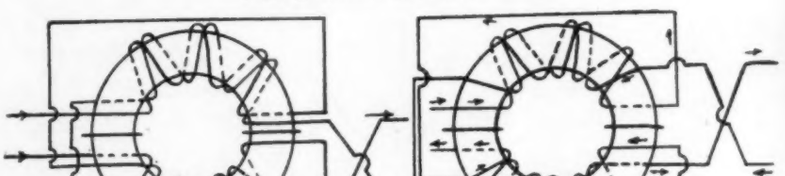
The transmission standard consists of an ordinary common battery instrument comprising a solid back transmitter, 60-ohm Bell receiver, 1,000-ohm magneto bell, 2-mf. condenser, induction coil 17/26 ohms, with a 300-ohm resistance to represent the subscriber's loop, connected to a 24-volt battery through the ordinary common battery cord circuit consisting of a toroidal repeating coil having four 22.5-ohm windings and a supervisory relay of 70 ohms, shunted by a non-inductive resistance of 30 ohms. There is nothing special about either the standard cable or the transmission standard. Both are in everyday commercial use and were adopted as convenient representations of good commercial transmission. For convenience, the actual cable is generally replaced by an equivalent artificial cable having the same constants as the standard cable, and arranged in sections so that by throwing switches mounted on the box containing the cable, any desired length within limits can be cut in or out of circuit. Fig. 7 shows diagrammatically the circuit arrangement of an artificial standard cable and the terminal transmission standards. The use of these standards has given rise to the terms "equated length," "transmission equivalent," and "transmission loss" expressed in miles of standard cable. For instance, if a repeating coil is stated to have a transmission loss of .5 mile, it means that the insertion of this coil in a telephone circuit has the same effect on transmission as if .5 mile of standard cable had been cut in. Fig. 8 shows the method of comparing an existing line with the standard. A list of transmission equivalents for different cables and wires, etc., is given in Appendix No. II.

COMMERCIAL LOADING COILS.

There are a number of different types of loading coil manufactured for different purposes, i.e., for light, medium, or heavy loading, and for phantom working, for either underground, aerial, or submarine use. The following types are those generally used by the British postoffice, manufactured by the Western Electric Company:



(a) ORDINARY LOADING COIL



(b) LOADING COIL FOR PHANTOMED CIRCUITS.

Fig. 5—Showing Current Flow in Phantomed Circuits.

Cable Loading Coils

Coil No.	Constants at 1,800 p.p.s. Effective Resistance R (ohms)	Effective Inductance L (henry)	Average Value R/L at 800 p.p.s.	Insulation Breakdown Test
506	27.0	.240—.2	50	500 Volts A.C.
507	14.0	.125—.1	50	500 Volts A.C.
508	20.0	.165—.1	50	500 Volts A.C.
514	19.0	.165—.185	50	500 Volts A.C.
515	29.0	.240—.260	50	500 Volts A.C.
535	14.0	.125—.145	50	500 Volts A.C.
513*	10.0	.100—.112	35	500 Volts A.C.
530*	16.0	.145—.165	35	500 Volts A.C.
536*	9.0	.077—.087	35	500 Volts A.C.

*Phantom coils.

"Loading Units" are made up as as follows:

1 No. 511 (phantom circuit) coil.
2 No. 512 (side circuit) coils.
1 No. 537 (phantom circuit) coil.
1 No. 517 (side circuit) coil.
1 No. 549 (phantom circuit) coil.
2 No. 550 (side circuit) coils.

The Nos. 512, 517 and 4112 coils and the associated phantom coils are designed for use on conductors of 150 to 400 pounds per mile. The Nos. 550 and 549 for 400-pound conductors with repeaters.

Coils for aerial loading are mounted in cases, bolted to the pole cross-arm.

Phantom "Loading Units" are made up as follows:

1 No. 536 and 2 No. 535 coils—"light" loading.
1 No. 513 and 2 No. 514 coils—"medium" loading.
1 No. 530 and 2 No. 515 coils—"heavy" loading.

Ordinary twinned conductor (non-phantomed) cables are seldom loaded now, but coils 506, 507 and 508 are suitable for this purpose. They are not suitable for phantom working. The No. 507 has been adopted in Great Britain as the standard for non-duplexed cables, using a spacing of 2.5 miles.

Coils for Aerial Loading

Coil No.	Constants at 1,800 p.p.s. Effective Resistance R (ohms)	Effective Inductance L (henry)	Average Value R/L at 800 p.p.s.	Insulation Breakdown Test
512	16.5	.250—.280	25	8,000 Volts A.C.
517	10.5	.150—.170	25	8,000 Volts A.C.
550	21.0	.244—.249	30	8,000 Volts A.C.
4112	19.0	.250—.280	35	8,000 Volts A.C.
511	9.0	.153—.173	25	8,000 Volts A.C.
537	6.0	.909—.100	25	8,000 Volts A.C.
549	11.5	.149—.152	30	8,000 Volts A.C.

For phantom working, the three coils of the unit are mounted in one case. The frequency of 1,800 p.p.s. is that used for testing at the factory, as this affords a more searching test than in testing with the mean frequency of 800 p.p.s. The average value of R/L at the latter frequency, used in transmission calculations, is given for reference. The test at 1,800 p.p.s. serves to show that the constants of the coils are within certain limits for the highest speech frequency. The effective resistance at the higher frequency is about twice as great as for the average frequency.

Coils for underground cables are mounted in cases containing from 4 to 98 coils, according to requirements, the cases being placed in manholes.

LOADING OF SUBMARINE CABLES.

The increase of the inductance of submarine cables to make transoceanic telephony possible was the subject of Prof. S. P. Thompson's paper, "Ocean Telephony" (read before the Electrical Congress at Chicago in 1893). He suggested, as stated in the earlier part of this paper, the provision of shunts of high inductance between conductors. While the production of a loaded cable capable of transmitting speech across the Atlantic may be possible, its commercial utility would be limited by the difference in time between Europe and America. Loaded telephone cables made in accordance with the method devised by C. E. Krarup, of the Danish Telegraph Administration, were laid off the coast of Germany and elsewhere as far back as 1902. This method consisted in covering the conductors with a spiral wrapping of fine iron wire. This type of cable is comparatively convenient to handle; it has the advantage that its added inductance is uniformly distributed, and it lends itself readily to phantom working, being more easily balanced. It is, however, costly, and the amount of inductance obtained is very limited.

A cable loaded with Pupin coils was laid by Siemens and Halske across Lake Constance in 1906. This cable is 9⅓ miles long and has 14 conductors, resistance 32 ohms per loop-mile, paper insulated, the core being wound with steel wire to preserve the formation, lead covered, and sheathed over all. The loading coils are inserted at intervals of 1,100 yards, and the attenuation constant is about .01 per mile.*

*See Mr. T. Plummer's paper of Dec. 3rd, 1906—P. O. Institution of Electrical Engineers; also Electrician, May 24th, 1907. Also for details of loaded submarine cables, "Submarine Cables for long-distance Telephone Circuits," Major O'Meare, C.M.G., I.E.E., London, November, 1910.

Phantom working has been successfully carried on in the continuously loaded Anglo-French cable between Abbots Cliff and Griznez (J. G. Hill, "Telephonic Transmission, etc.," 1920, p. 208).

A four-core telephone cable, manufactured by Siemens Bros., of Woolwich, provided with loading coils made by the Western Electric Company, was laid across the channel in 1910. An interesting description of the construction, laying, and tests on this cable is given by Major O'Meara (see note). The mean gain in transmission computed from speaking tests made by four observers was equivalent to 17 miles of standard cable.

REFLECTION AND TERMINAL LOSSES.

In any line along which electromagnetic waves are propagated, reflection will take place wherever the line changes in characteristics; *e.g.*, in the transition from an open wire line to an underground cable, at the open end of a line, or where the line is connected to repeating coils, etc., or to a telephone instrument. The only case where reflection would not occur is in the imaginary one of an infinite line. In dealing with the actions that occur in actual circuits there are three possible cases:

(1) That of a line open or insulated at the receiving end.

(2) Short-circuited at the receiving end.

(3) Closed at the receiving end by an instrument of given impedance.

The phenomena that take place due to reflection are very complex and difficult to explain, although their action can be demonstrated mechanically by experiments with vibrating strings.

In the case of a line of finite length open at the receiving end, an electromagnetic wave is brought momentarily to rest on arriving at the end, and is then re-established, traveling back to the starting point, and so on, being reflected backward and forward till its energy is dissipated.

From this may occur the paradoxical effect that the voltage at the receiving end is greater than that at the sending end, but there is generally a considerable difference of phase between them. When a line is short-circuited at the receiving end, electromagnetic waves traveling along it are momentarily reflected at the short-circuit, and if trains of waves are continually being propagated along the line, the direct and reflected trains pass through one another, producing a complicated condition due to interference. The action of reflection of electromagnetic waves is analogous to the conditions that are set up when sound waves are traveling up an organ pipe, the insulated line being comparable to the closed pipe, and the short-circuited line to the open pipe. If the receiving end of the line is not perfectly insulated, or if the line is closed by a circuit of appreciable impedance, the waves will be partly reflected and partly transmitted. Consequently, if at any point in the line there occurs a sudden change in capacity or inductance, there will be partial reflection. The case where the

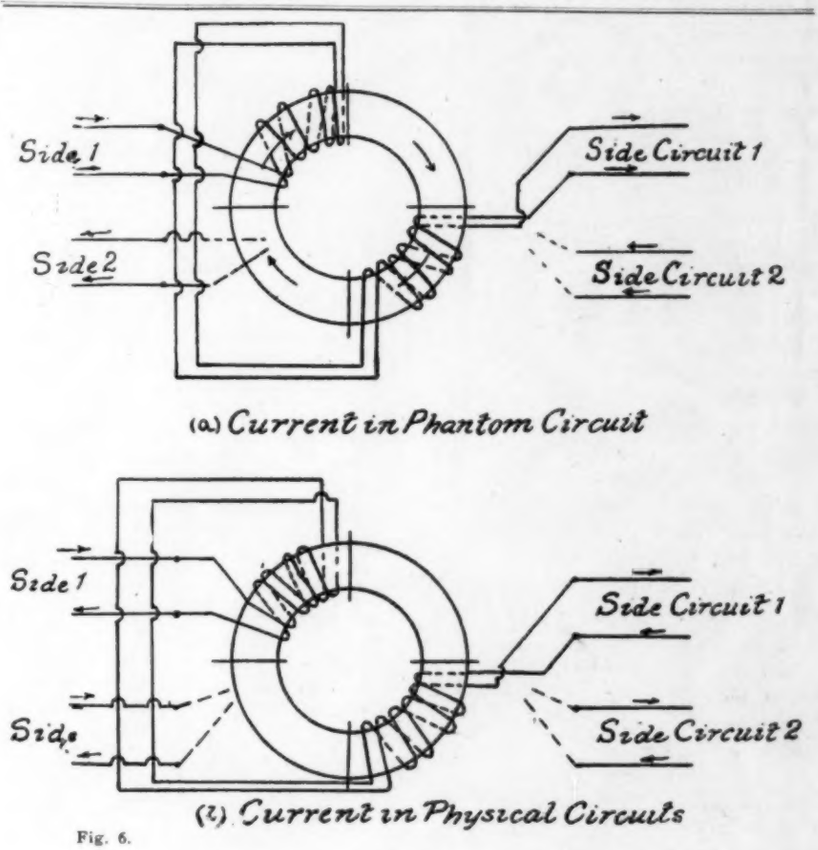


Fig. 6.

receiving end is closed by some instrument of known impedance is the problem met with in practice, and is unfortunately the most complicated of the three. It can be shown mathematically how to arrive by calculation at the relation between sent and received current in a circuit of finite length with known impedance, but time and space will not permit of the development of the formulæ here.

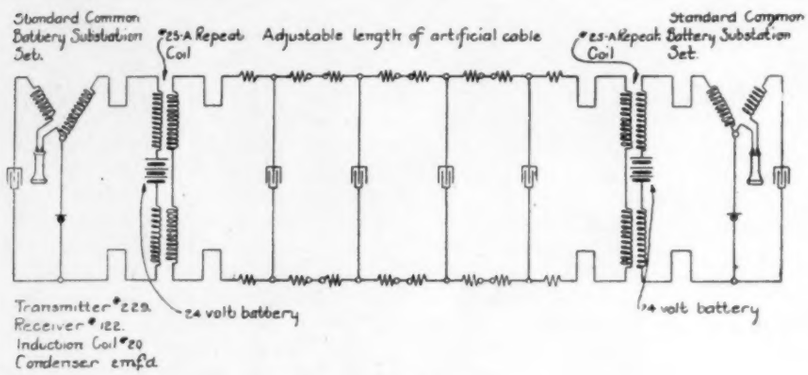


Fig. 7.

They will be found in Appendix I.

It will be sufficient to state that in practice the following conclusions have been arrived at by experiment: Reflection is not important which occurs (*a*) at the junctions of unloaded sections of line of different types; (*b*) at the junction of an unloaded line to a terminal instrument. There is, however, considerable reflection loss when a heavily loaded line is terminated on an instrument, but it has been found that if a loaded line be connected to the termination through a length of unloaded line this loss is considerably reduced, and may be entirely eliminated. This effect is known as "tapering." A similar effect can be produced by the use of suitable terminal transformers, or by gradually reducing the inductance of successive loading coils as the line approaches the termination. It may be noted here that subscribers' local lines themselves act as tapers when connected to loaded junctions.

IMPEDANCE OF TELEPHONE APPARATUS.

Even after the general results of Pupin's investigations became fairly well known, the importance of attention to the loss that might occur in apparatus bridged on the line, or at the terminal station was not fully recognized.

As I think Mr. Gherardi mentions in one of his papers on the subject, it is false economy to spend large sums on improving the line when the apparatus used at either end may be inefficient from the transmission standpoint, and may introduce losses which could be eliminated by re-design at a comparatively small outlay, considering the enormous difference between the cost of the line plant and that of the exchange and subscribers' stations.

Attention has of recent years been closely applied to this question. The example given in the section of this paper dealing with phantom circuit repeating coils shows what can be done in this direction. The results obtained by measurement of the impedance and transmission loss of different kinds of apparatus used in telephone exchange circuits give some curious and unexpected results. For example, it was thought at one time that a bridging coil of 1,000 ohms resistance (d.c.) had no perceptible effect on speaking circuit, while the effect of a coil having a considerably lower ohmic resistance might be serious; whereas the results of quantitative tests show that the ohmic resistance when measured with direct current is no guide to the behavior of the apparatus when traversed by currents at telephonic frequency. This is because, besides ohmic resistance, all apparatus has both inductance and capacity to a greater or less extent. Also the ohmic resistance to direct currents is considerably less than that to alternating currents having frequencies of the order of 800 p.p.s. owing to eddy currents, skin effect, and hysteresis. The ohmic resistance as measured at telephonic frequency is termed "effective resistance," and may be as much as twenty times as great as the direct current resistance.

An interesting article by B. S. Cohen on the subject of the impedance of telephonic apparatus was published in the *National Telephone Journal* some years ago, and some of the information there given is reproduced here.

As the impedance of telephone apparatus shunted across the line or in series depends on a number of factors, some of which are the dimensions, shape and number of turns of the coil winding, and the nature, dimensions and subdivision of the core, it is impossible to calculate it with any degree of accuracy. Mr. Cohen devised a method of measurement, fully described in the article referred to, using a testing current of sine-wave form, of an amplitude of from .3 to 2 m.a. and a frequency of 1,000 p.p.s., which had been determined by previous researches to approximate very closely to the results that would be obtained with actual speech currents. A table showing some of Mr. Cohen's results will be found in Appendix III. Some of the interesting results obtained from these tests are that the impedance of relays and signals is different when operated from the impedance when not operated, due to the change in the configuration of the magnetic circuit. Also, the impedance of a local battery telephone is less when the speaking key of the hand set is up than when it is pressed. Consequently, having the key up when listening not only saves drain on the batteries but improves reception. Mr. Cohen also finds that the effective resistance of differentially wound coils is more than double that of non-differential coils, while the inductance is under a quarter. This result is due to the effect of the mutual capacity between the two windings, this amounting in the case of a 1,000-ohm indicator to .064 mf.—.010 mf. more than the mutual capacity of a loop mile of standard cable.

Mr. Cohen suggests that the great increase in effective resistance when capacity is present is due to energy loss in the dielectric.

COMMERCIAL ASPECTS OF LOADING.

The objects desired in loading a telephone line are either:

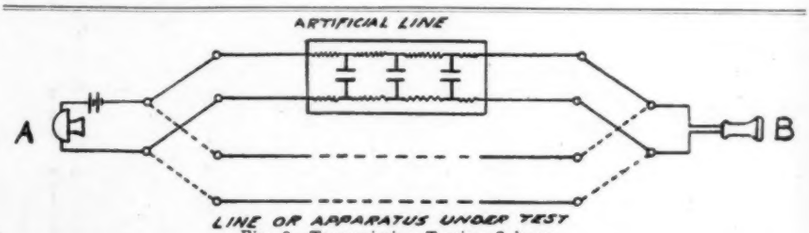


Fig. 8—Transmission Testing Scheme.

(1) To improve transmission on an existing line.

(2) When constructing a new line, to enable a smaller gauge conductor to be used than would give the desired grade of transmission without loading.

(3) To run lines within reasonable limits of expenditure which will provide commercial transmission over greater distances than can be attained with the heaviest gauge unloaded conductor it is practicable to use.

In cases (1) and (2) the following questions affect the decision whether the line be loaded or not:—The saving in interest on the value of copper, duct space, etc., saved must be placed against the interest on the capital cost of loading and the additional annual charge for maintenance (if any).

In planning a transmission scheme for a given area, a set of standards must be adopted at the start for the grade of transmission to be given in different circumstances. Obviously, it is not economically possible to provide subscribers with equivalent transmission between, say, Johannesburg and Lourenco Marques as between Johannesburg and Pretoria, or between subscribers in the Johannesburg municipal area. This fact is ignored by the public generally, it being usually imagined that, once a line is in existence, conversation should be as easily carried on over it, whatever its length, as if the two speakers were in adjacent buildings. They would be astonished if they were told the cost of a 3-minute conversation under these conditions. It should be pointed out, however, that the advent of the repeater, which is not under consideration here, materially alters this aspect of the case. The standards of transmission to be provided by the postoffice in Great Britain and Ireland were laid down by the engineer-in-chief in 1915 as follows:

"The audibility shall not be worse than that obtained from two standard telephones separated by the length of standard cable shown opposite the different classes of service detailed below:

I. Between stations in the same urban area..... 20 M.S.C.

II. Between—
(*a*) stations on the same zone .....
(*b*) stations adjacent zones and not more than 200 miles apart.....
(*c*) stations in any two large commercial centers where traffic is sufficient to justify direct lines between local exchanges, *e.g.*, London-Birmingham, London-Liverpool, Bristol-Cardiff. 25 M.S.C.

III. Between—
(*a*) stations in adjacent zones and more than 200 miles apart, *e.g.*, Ipswich-Exeter .....
(*b*) stations in different (not adjacent) zones and not more than 300 miles apart
(*c*) stations (on central exchanges) in any two large commercial centers from 300 to 400 miles apart, *e.g.*, London-Dublin, London-Glasgow ..... 30 M.S.C.

IV. General standard for long-distance communication between stations in Great Britain and Ireland, and not included in any of the foregoing ..... 35 M.S.C.

There is some difference of opinion, naturally, between different observers as to the practical limiting distance for speech transmission, expressed in miles of standard cable, varying from 40 to 55 miles, but it will be seen that those adopted by the British postoffice are well within the lower of these. Having decided on the grades of transmission to be given, decision as to the type of cable to be used, loaded or not loaded, etc., can be determined. In the foregoing it is assumed that the central office is in existence and the type of switchboard to be used, C.B. manual, C.B. automatic, or magneto, has been settled. For an area hitherto unprovided with telephone service, the transmission scheme would be bound up with these and other considerations, such as the location of the exchange, the probable growth of the scope of this paper.*

*For a discussion of cost problems in transmission see Mr. J. G. Hill's "Telephonic Transmission, etc.," Chapter XII. Also Messrs. A. B. Hart & W. J. Hilyer, "Trunk Telephone Transmission Schemes," P.O. I.E.E. (Electrician, London, April 11th, 1913). On the locations of Telephone Exchanges see Mr. T. Pearson's paper, S.A.I.E.E., (May, 1915).

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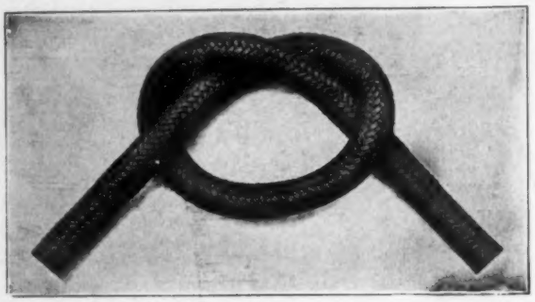

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